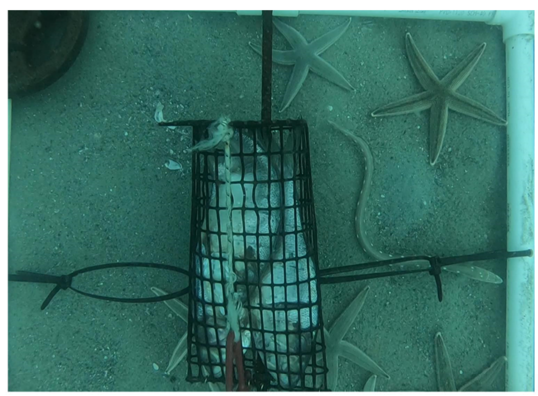
Charleston Harbor Post 45:

Biological Monitoring and Sediment Sampling at the Charleston ODMDS

2017–2019 Final Report (Job 2)
To
The U.S. Army Corps of Engineers, Charleston District



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Charleston Harbor Post 45: Biological Monitoring and Sediment Sampling at the Charleston ODMDS

Final Report (2017–2019)

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Table of Contents

Executive Summary

In fall 2017, the South Carolina Department of Natural Resources (SCDNR), in cooperation with the U.S. Army Corps of Engineers (USACE) initiated a two-part (and two-year) study to assess biological impacts following activities in the Ocean Dredge Material Disposal Site (ODMDS) located south of the shipping channel. The first part was to complete a baseline assessment of sediment characteristics and associated benthic infaunal communities in areas adjacent to the ODMDS (Johnson et al., 2020). The second part, which is included in this report, was to characterize the habitat and associated epifaunal organisms and fish assemblages at sand sites where the rock berm was to be constructed and at sand sites and natural hard bottom sites adjacent to the ODMDS to assess sediment movement during placement. This report evaluates temporal shifts in fish and invertebrate communities assessed using visual data collected by scientific divers and remotely operated video cameras. These additional data sets were included in the monitoring plan to assess potential impacts at higher trophic levels than traditionally evaluated in such studies. Sediment transport trends assessed from visual observations and physical sediment collection were also included to provide context for evaluating changes in faunal assemblages, as well as to characterize the extent to which sediment loads were redistributed.

Baseline visual surveys were conducted at 42 sites on five survey dates between 29 November 2017 and 22 January 2018. Thirty sites were located in the future footprints of the western, southern, and eastern rock berms that were created during this study, and as such each was only surveyed once by divers (3.4 video hours) and by remotely operated video cameras (30.1 video hours) that were baited for animal attraction. Remotely collected baited video was particularly valuable in this study because it was the only visual data collection technique that uniformly surveyed all 12 temporal monitoring sites. Across all 42 sites and techniques, 23 fish species were documented. Irrespective of survey methodology, finfish species were infrequently observed; however, when seen, observations were greatest at sites associated with greater habitat complexity (e.g., some level of hard bottom).

Fifty-one invertebrate classifications totaling 2,362 organisms were recorded from diver video, which were infrequently encountered in baited video. Sea fingers (*Titanideum* sp.) and finger sponges (*Haliclona* sp.) comprised 68% of invertebrate counts in diver videos but occurred exclusively at three sites with hard bottom habitat (HB1, HB2, and I4). Conversely, sea whips (*Leptogorgia virgulata*) and gray sea stars (*Luidia clathrata*) were more widely distributed, and occurred in 76% and 67% of diver surveys, respectively. Lastly, as baited video cameras were retrieved and passed over an unknown expanse of seafloor in fall 2019, the final frames recorded provided qualitative reassurance that sponge and soft coral communities were not drastically altered at two biologically diverse hard bottom sites that were unable to be surveyed by scientific divers after spring 2018.

Twelve sites, located outside of the berm footprint, were proposed for semi-annual temporal monitoring starting with fall 2017 and spring 2018 (30 April to 2 May) as baseline assessments prior to placement of material in the ODMDS or berm. Unfortunately, reduced visibility and competing operational interests in the ODMDS area restricted the diver surveys to five sites in fall 2018 (13 December to 17 January), no surveys were completed in spring 2019,

and only eight sites were able to be surveyed in fall 2019 (6 to 16 December). Baited video surveys at all 12 temporal monitoring sites occurred in all but spring 2019. Only 234 fish were observed across diver video (4.3 hours) and only 178 fish were seen across baited video (53.1 hours), which made this data set difficult to analyze statistically. The most compelling observation of change related to sediment placement were associated with Black sea bass: sightings declined by >90% between fall 2017 and spring 2018 in diver and baited video surveys but returned to fall 2017 levels by fall 2019 in baited video, suggesting only ephemeral disturbance to this species. In contrast, a total of 4,093 invertebrate counts were recorded across diver surveys at monitoring sites, 77% of which occurred at two hard bottom sites (HB1, HB2) that were only able to be surveyed in fall 2017 and spring 2018. Reduced ability to survey these sites due to poor visibility confounded the ability to draw conclusions regarding invertebrate distributions; however, similar to Black sea bass, prevalent sessile invertebrate species were observed less frequently in spring 2018 during placement activities compared to the pre-placement time period in fall 2017. Overall, temporal shifts in fish and invertebrate assemblages were best described as dynamic with no clear impacts observed.

Four acoustic receivers deployed in predominantly sand habitats along the southern and western borders of the ODMDS provided continuous monitoring capability between 22 January 2018 and 16 December 2019. Acoustic receiver monitoring also occurred at a dense hard bottom site between 22 January 2018 and 17 January 2019; however, the entire receiver and screw anchor attachment were missing on 16 December 2019. During this study, 253 transmitters were detected 6,757 times, representing 15 large marine species that were virtually absent from visual surveys. Seasonal detection patterns resembled other locations monitored in the South Carolina coastal plain, suggesting minimal impact on the anticipated occurrence of mobile species in the ODMDS area. Atlantic sturgeon (*Acipenser oxyrhinchus*) tagged by 10 research groups comprised >40% of transmitter codes detected and nearly half of all detections recorded with data generation similar across monitoring years (2018, 2019). Cobia (*Rachycentron canadum*) tagged by six research groups accounted for 13% of transmitter codes but 27% of detection data. Cobia were detected more frequently in 2019 than 2018; however, 75% of increased cobia detection in 2019 was attributed to a single fish detected more than four times as much as the most detected cobia in 2018. White (*Carcharodon carcharias*), Tiger (*Galeocerdo cuvier*), and Blacktip (*Carcharhinus limbatus*) sharks collectively accounted for 28% of acoustic transmitters and 19% of detections; White and Tiger sharks were more frequently detected in 2019, but Blacktip sharks were more frequently detected in 2018. Ten remaining species comprised just 17% of transmitter codes and 7% of transmitter detections. The occurrence these species in the ODMDS throughout the study demonstrates the lack of extended avoidance concurrent with dredge spoil material placement in the immediate vicinity.

Overall, sediment accumulation in the sediment traps was of fine materials with high content of silt and clay as well as fine sand particles. The amount of accumulation of sediment was different along the western half of the sites in comparison to the eastern half of the sites. It is unclear if this is due to dredging, placement, or natural sediment transport from the Charleston Harbor plume. Additional spatial location data for dredging and placement would provide more information to determine if the spatial and sampling event patterns were related to these activities. The lack of higher silt and clay materials in the seafloor sediment adjacent to the increased levels in the sediment traps indicates that if dredged material is moving across one of the sampling sites that there is no retention of the silt and clay at these sites on the seafloor. Qualitative, visual assessment of the survey sites by scientific divers initially suggested finer sediment distribution beginning in spring 2018 but with a return to more baseline (fall 2017) conditions by fall 2019, suggesting that 'silting' effects were relatively short-lived and began to resolve within the timeline that monitoring was conducted.

Introduction

The Charleston, South Carolina, Ocean Dredged Material Disposal Site (ODMDS) is one of the most active and frequently used sites in the South Atlantic Bight. It has historically been used primarily by the U.S. Army Corps of Engineers (USACE) and the South Carolina State Ports Authority (SCSPA) to dispose of bottom sediments derived from maintenance dredging and deepening projects in the Charleston Harbor estuary and entrance channel (Charleston ODMDS Site Management and Monitoring Plan (SMMP), 2016). Since 1987, approximately 52 million cubic yards of dredged material has been placed within the Charleston ODMDS and it is estimated that an additional 65 million cubic yards of dredge material emanating from new work and maintenance dredging will be placed in the placement site over the next twenty-five years (SMMP, 2016).

The original Management Plan for ocean dredged material placement for the Charleston Harbor complex (1987) established a smaller permanent ODMDS 2.8 x 1.1 nautical miles in size, surrounded by a larger ODMDS 5.3 x 2.3 nautical miles in size. However, placement activities within the smaller ODMDS were found to impact previously unidentified live bottom habitat present within the site resulting in a re-designation of the site boundaries to avoid impacting these critical areas (Winn et al., 1989). The re-designated ODMDS was established in 1993 by an Interagency Task Force and consists of a four square-mile area contained within the larger ODMDS site and partially overlapping with the original smaller ODMDS. Following the re-designation of the ODMDS and the approval of a new SMMP in 1995, placement of new work dredge material from the Charleston Harbor Deepening Project (CHDP) within the 1993 ODMDS began in 1999 and continued through 2002. As a result of the improvements to navigation effected by the 1999-2002 CHDP, the USACE Charleston District proposed several additional modifications to accommodate the needs of future shipping traffic, specifically the deepening and widening of portions of the federal navigation channel, and the establishment of a new ODMDS with a total area of 9.8 square miles and the construction of a new U-shaped berm consisting of dredge material.

Thus, in fall 2017, a multi-year project commenced to deepen and widen the shipping entrance channel for Charleston Harbor, SC to accommodate larger cargo ships. Consistent with prior sand dredging operations at this location, sediment associated with this channel modification project was deposited in the ODMDS located several miles south of the shipping channel. However, in contrast to prior sediment relocation efforts, rock rubble removed concurrent with deepening was placed along the western, southern, and eastern borders of the ODMDS to create the U-shaped berm measuring approximately 122 m wide x 1.2-m tall and at least 4,572 m long for each of the three berm sides. The purpose of the U-shaped berm (described in more detail in Final Report for Job 1 of this award, Johnson et al., 2020) was to minimize the movement of deposited material away from the disposal zone, which was deposited within the ODMDS concurrent with berm construction during the present study.

The Charleston ODMDS, due to its status as one of the most frequently used sites in the South Atlantic Bight, is consequently one of the most extensively monitored. Monitoring efforts have included bathymetric surveys, examination of sediment characteristics and contamination, gamma isotope mapping of bottom sediments, assessment of macrobenthic infaunal invertebrate communities, and hydrographic surveys. Multiple monitoring studies of the Charleston ODMDS have examined sediment composition. The earliest baseline assessment of sediment characteristics was completed in 1978 by the South Carolina Wildlife and Marine Resources Department (SCWMRD, 1979). However, the re-designation of the boundaries of the ODMDS in 1993 created the need for a new assessment. In 1993 and 1994, a total of 200 sediment samples each year were collected in and around the disposal zone (Van Dolah et al., 1996, 1997). Analysis of these samples showed that the dominant sediment type in the ODMDS was fine-grained sands with variable concentrations of silt/clay and shell hash. Additional sediment composition assessments of the ODMDS were completed in 2000, approximately halfway through the 1999-2002 CHDP (Jutte et al., 2001) and again in 2002 following completion (Jutte et al., 2005). Comparison between pre-impact (1993-1994), interim (2000), and post-impact (2002) showed changes in the silt/clay and shell hash content of bottom sediments both within the placement areas as well as in the inner and outer boundary zones, indicating that impacts from placement activities were not limited to the disposal zone. Possible drivers of this change include the migration of deposited sediments from the disposal zone and unauthorized placement of dredged material outside the disposal zone (Jutte et al., 2005).

The goal of this report and the monitoring of the current dredging operation was for the SCDNR to address the effectiveness of the berm by (a) assessing baseline conditions as close to pre-berm construction as possible and (b) conducting temporal monitoring for two years at sites external to the disposal zone. This would allow the SCDNR to characterize the effects of sediment movement and berm construction on fish assemblages at sand, man-made hard bottom, and natural hard bottom habitats, and to assess whether berms restrict sediment flow. Biological emphasis was placed on both fish and invertebrate communities using diver surveys and baited videos. Geological emphasis was placed on sediment characteristics in sediment traps and adjacent surface sediments. Although before, during, and after disturbance data collection periods would have been ideal, due to channel deepening and widening requiring several years, this study only focused on the before (fall 2017) and during (2018–2019) phases. Following berm construction completion, a post-construction project would be needed to quantify longer-term ecological shifts.

Methods

Site Selection

To assess potential effects of berm creation on biological processes, three general habitat types were included in this study (Appendix 1): (a) 30 presumably sand bottom sites in each of western, southern, and eastern berm creation areas; (b) eight presumably sand bottom sites located outside of the disposal zone in the Inner Boundary zone; and (c) four presumably hard bottom located within a nautical mile of the southwest berm corner.

In each of the three berm creation areas (aka, “arms”), 10 centralized latitude/longitude coordinates were randomly selected per arm for a total of 30 survey sites (Figure 1). Dive sites were selected randomly along the center axis of each berm area, given that the central axis (a) should have the highest probability of receiving future berm material and (b) should also contain the greatest vertical build-up of future berm material. Central latitude/longitude coordinates for each of the eight Inner Boundary (I1 through I8) zones recognized for the

ODMDS were selected as temporal monitoring sites (Figure 1). Lastly, four monitoring sites in a historically hard bottom area located mostly in the southwest corner of Outer Boundary zone O7 were also included for temporal monitoring. Hard bottom sites were spaced along the central axis of the two densest hard bottom signatures noted from previous studies (Figure 1).

Diver Surveys

At each of 30 future berm and 12 temporal monitoring sites, a pair of scientific divers recorded a visual survey with a GoPro (Hero 3) camera. Upon reaching the seafloor, the first diver attached one end of a 12.2-m lanyard to the descent line anchor, then swam away from the descent line anchor until the lanyard became taught. After placing an orange fiberglass stake in the sediment to visually mark the lanyard terminus (and the start of the survey), this diver swam the taut lanyard a full 360º until returning to the fiberglass marker stake. Concurrent with the first diver slowly (~0.15 m per second) swimming an arc, the second diver swam back and forth along the line to film (GoPro Hero 3) the seafloor located within the arc (467 m^2).

Diver video surveys were reviewed in the laboratory, and a count of all organisms was recorded along with the time of observation in the video file. Due to the non-linear nature of surveys, seafloor features provided a relative reference to ensure that organisms were not repeat counted. All organisms were identified to the lowest possible taxon, along with a time of observation. For the octocoral *Titanidium* sp., multiple basal stems were considered a cluster if less than 7.6 cm (estimated) of sand occurred between basal stems, and clusters (vs. stems) were counted. For colonial sponges, any amount of sand between sponge material protruding from the seafloor was used to delineate clusters (the unit of enumeration); however, White crown (*Ciocalapata gibbsi*) and Yellow crown (*Raspailia* sp.) sponges protruded from the seafloor in a cluster of spikes with traces of sediment interspersed between spikes.

Diver video observation data were managed in MS Access 18 (Microsoft®, Redmond, WA). For the first data collection cycle (fall/winter 2017), descriptive statistics were used to characterize frequency of occurrence and relative abundance of taxa among three berm arms (W1-W10; S1-S10; E1-E10), Inner Boundary sites (I1-I8), and hard bottom sites (HB1-HB4). These metrics were also used in cluster analysis evaluate temporal change at I1-I8 and HB1-HB4.

Baited Video

Downward-facing Hero 3 GoPro cameras were secured at the top of a 61-cm x 61-cm x 61-cm (2-ft x 2-ft x 2-ft) PVC frame (Schedule 40, 2.54 cm or 1 inch diameter), directly above a bait bin that typically contained Spot (*Leiostomus xanthurus*). PVC frames were lowered to the seafloor and soaked for an hour to document species that might have been missed by scientific divers. Baited video was reviewed in the laboratory using similar protocols as diver surveys and managed in the same MS Access database. Maximum instantaneous count per species was analyzed for each baited video deployment to ensure that individual organisms were not counted more than once.

Acoustic Telemetry Monitoring

To further assess the potential influence of berm creation on fish assemblages, acoustic receivers (VR2W, Vemco/Innovasea) were deployed at three presumably hard bottom sites and two Inner Boundary zone sites adjacent to the southern berm arm. Acoustic receivers were secured to the top of 1.2-m (4-ft) galvanized dipped iron screw anchors and situated 0.61 m above the seafloor (Figure 2). Acoustic receivers were retrieved during scientific diving operations, and data were uploaded and managed concurrent with on-going research efforts by the SCDNR (http://dnr.sc.gov/marine/receiverstudy/methods.html; Accessed 13 February 2020). Regional networks enabled detected transmitters to be matched to species and research tagging group.

Seafloor Attributes

Seafloor attributes (Table 1) noted throughout diver surveys were used to qualify seafloor type, and initial seafloor assessments in fall 2017 were used to group sites using Hierarchical cluster analysis (Single linkage, Euclidean distance) in Minitab 18®. Temporal change in seafloor features between fall 2017 and fall 2019 was also assessed descriptively for 12 monitoring sites.

Sediment Analysis

To quantify sediment changes during this study, sediment traps (Figure 3) were deployed to capture the relative sediment accumulation rates and the composition of the material in the trap. The traps were constructed of PVC that was 46 cm in length with an inside diameter of 5.08 cm (20.27 cm^2 trap area) and equipped with a baffle system of smaller tubes inside. PVC sediment traps were positioned 0.6 meters above the seafloor and secured with heavy duty zip ties to iron re-bar (1.3 cm x 1.2 meters) staked into the seafloor such that the opening of the trap was ~1 m off the bottom. A single sediment trap was deployed in the center of each Inner Boundary zone and at three of the four Hard Bottom monitoring sites. The methods were similar to those of the 2001–2005 ODMDS monitoring study (SCDNR 2005) except the inner diameter of the previous study sediment trap was 5.8 cm or 26.42 cm^2 trap area; only a single trap was deployed at each site in this study in comparison to 3 replicate traps in the previous study; and the trap deployments were longer (e.g., ~100-365 days) in this study compared to the previous study (average of 34 days).

The sediment traps were first deployed in the fall 2017 to winter 2018 (December 2017 and January 2018) and the sediment was retrieved in the spring 2018 for a range of 99-147 days deployed (Appendix 2). This deployment will be identified as fa17-sp18. Sediment from the traps at all but the I1 site was retrieved for a second time in the winter 2019 (January 2019) for a range of 259-261 days deployed. The I1 site was not accessible during this period due to active sediment placement. Site I1 was retrieved in the spring 2019 (May 2019) for a total of 378 days deployed. This deployment will be identified as sp18-wi19. The final retrieval occurred in fall 2019 (September, October, December 2019) for ranges of 140 (I1), 252-260 (I2, I3, I6, I8), and 325-332 (I4, I5, I7, HB2, HB3, HB4) days deployed (Appendix 2). This deployment will be identified as wi19-fa19. The sediment trap deployments may be impacted by the extended length of deployments as identified in the SCDNR (2005) study which discussed potential loss of material during winter storms, only a maximum volume can be held in each trap, and a change in the length to width ratio may lead to loss of material. These are all potential issues which cannot be ruled out as influencing the findings of this study.

The sediment trap samples were collected by divers and placed in plastic bags. Upon returning to the laboratory, samples were frozen until analysis. The sp18-wi19 samples from I7, I8, HB2, HB3, HB4 (traps and seafloor) and I6 (trap only) were not frozen until the following day. The only parameter that might be affected by this is total organic matter; however, there does not appear to be a consistent pattern that may indicated a concern compared to the other samples which were frozen immediately. Prior to analysis, samples were transferred to unagitated beakers and allowed to settle for a minimum of 12 hours to allow all silts and clays to settle and enable the removal of excess water.

In addition, seafloor sediment samples were collected during the winter 2019 and fall 2019 sampling events. A scoop of sediment was collected by diver from the seafloor adjacent to each sediment trap. The sediment was placed in a plastic bag and frozen until analysis.

Sediment composition analysis was performed to determine percentage (by weight) of sand, calcium carbonate ($CaCO_3$), silt, and clay following the methods described in Folk (1980) and Pequegnat et al. (1981). Total organic matter (TOM) percentage (by weight) of samples was analyzed as described by Plumb (1981). Sand grain size or phi analysis was performed. Sand fractions from the first analysis were dry-sieved through a set of fourteen 0.5 phi-interval screens (-2.0 representing pebble gravel and larger to 4.0 indicating very fine sand) using a Ro-Tap mechanical shaker. Weights were obtained for each phi size, where phi = -log2 (grain diameter in mm) according to the Udden-Wentworth Phi classification (Brown and McLachlan 1990). Lastly, overall weight (in grams) of the accumulated material in the sediment traps was determined by transferring sediment trap material from the collection bag to a pre-weighed glass beaker, then drying at 90°C until thoroughly dried. The samples were then cooled to ambient temperature and weighed.

For Quality Assurance/Quality Control (QAQC), the dried material used to determine overall weight from the fa17-sp18 and sp18-wi19 sampling events was re-hydrated and sample material for analysis was extracted. For the wi19-fa19 sampling event, subsamples for QAQC were removed prior to drying. In all cases, any sample material used for the initial or QAQC analysis was considered in determining the overall weight of the accumulated sediment trap sample. QAQC was deemed passing if there was a difference of less than 10% in the dominant component between the original and QAQC results.

Results

Fall/Winter 2017: Berm vs. Monitoring Sites

On four field days between 29 November and 5 December 2017 (fall 2017), 3.4 hours of diver video and 30.1 hours of baited video were recorded across 30 future berm sites. Median water temperature was 63°F and median diver-estimated visibility was 18 feet (minimum = 7 feet). Water depth distributions were similar for the southern (42 to 54 feet) and eastern (41 to 53 feet) berm arm sites, but slightly shallower (32 to 46 feet) for western berm arm sites.

Baseline diver video (1.4 hours) and baited video (15.9 hours) were also collected at 12 temporal monitoring sites on 5 December 2017 and 22 January 2018 (fall 2017). Water depth distribution (median = 48 feet, range = 41 to 55 feet) and visibility (median = 18 feet, minimum = 5 feet) were comparable to berm arm sites; however, due to later survey dates, baseline observations were collected at a cooler (56°F) median water temperature.

Across all 42 sites and survey technique, 23 fish species (including two sharks and three rays) were documented (Table 2). Sharks and rays were infrequently seen (i.e., 1 to 7 sites), and when observed, were most often detected by baited video (Table 3). Fifteen of 18 finfish species were recorded by diver video, with 12 species only being recorded by diver video (Table 2). Among six finfish species recorded by baited video, half were only recorded with this technique (Table 2). Irrespective of survey methodology, finfish species were infrequently observed, with a maximum occurrence of 14 diver surveys (33%) for Inshore lizardfish (*Synodus foetens*) and a maximum occurrence of 12 baited surveys for Palespotted eels (*Ophichthus ocellatus*, Table 3). Both survey techniques also recorded finfish that could not be identified to species (Table 3).

With regards to relative abundance, no sharks, two rays, and 269 finfish were recorded by diver video (Table 3). Sixty-eight percent of finfish counts were Black sea bass (*Centropristis striata*) which were only seen along the western berm arm and adjacent hard bottom sites (Table 3). All remaining finfish species recorded by diver video occurred with gross relative abundances of less than one fish per survey (Table 3), and predominantly consisted of Longspine porgy (*Stenotomus aculeatus*), Sand perch (*Diplectum formosum*), and Inshore lizardfish. Black sea bass comprised 81% of the sum of maximum species counts across baited surveys, followed by Palespotted eels and Sand perch (Table 4). Similar to diver video, gross relative abundance of all species other than Black sea bass was less than one fish per baited video survey (Table 3).

Fifty-one invertebrate classifications were observed across 42 baseline site surveys, all but seven of which were recorded from diver video (Table 4). Sea whips (*Leptogorgia virgulata*) and Gray sea stars (*Luidia clathrata*) were the most frequently observed invertebrates and were recorded during 32 (76%) and 28 (67%) of site surveys (Table 4). Sea pens (*Virgularia presbytes*) and anemones (*Anemonia sargassensis*) were the third and fourth most frequently observed invertebrates, but only occurred at 15 (36%) and 11 (26%) of sites, respectively (Table 4). Conversely, invertebrate relative abundance was dominated by Sea fingers (*Titanideum* sp.) and Finger sponges (*Haliclona* sp.) which comprised 68% of 2,362 invertebrate counts recorded from diver videos and occurred exclusively at two Hard Bottom (HB1, HB2) and one Inner Boundary zone (I4) site (Table 4). Eight other sponge and four other soft coral classifications comprised 24% of invertebrate counts (n = 284 and 272, respectively) from diver video and were also primarily observed at two Hard Bottom and one Inner Boundary zone site; however, Sea pens and Sea whips were more evenly distributed across survey sites (Table 4). Only 18 (35%) invertebrate classifications were recorded by baited video, half of which were Crustaceans, followed by Echinoderms (4), Molluscs (3), and Cnidarians (2; Table 4). Excluding four crab species and Gray sea stars, only one organism per invertebrate species was recorded by baited video, with 128 organisms recorded across 42 baited video surveys (Table 4).

Temporal Monitoring: Overview

All 12 temporal monitoring sites were surveyed (diver and baited video) a second time between 30 April and 2 May 2018 (spring 2018), when median visibility was 10 feet and median water temperature was 68°F (Table 5). Material placement and reduced visibility (median = 5 feet) restricted diver surveys in fall 2018 (13 December to 17 January) to five Inner Boundary zone sites, predominantly located in the eastern half of the ODMDS (Table 5). Water temperature (median = 55°F) and survey dates were comparable to fall 2017, and baited surveys were also completed at all 12 temporal monitoring sites (Table 5). Due to continued material placement (and berm construction) in the ODMDS, and the need to establish survey sites for a companion USACE-funded study (W912HP-17-2-0002, Task 7), neither diver surveys nor baited video were attempted at temporal monitoring sites in spring 2019. Diver surveys and/or baited video were attempted on six dates between 23 September and 29 October 2019; however, due to poor visibility (median = 3 feet), data were not usable. As such, fall 2019 video data (diver and baited) were not collected until 6 and 16 December, but at comparable water temperature (median = 59°F) and visibility (median = 8 feet) as previous fall surveys (Table 5).

Temporal Monitoring: Fish

Fish species composition in diver video was comparable in fall 2017 (9) and fall 2019 (10), but reduced in spring 2018 (6) and no fish species were seen in fall 2018. Across seasonal survey periods, 18 fish identifications (totaling 234 fish) were recorded from diver video; however, 13 species were only observed during a single seasonal survey period and with a maximum of 19 individuals per species. Three species were seen in two periods, but with a maximum of 21 fish per species (Figure 3a). Black sea bass and Sand perch were the only species observed during three seasonal survey periods; however, only 13 total Sand perch were observed (Figure 3a). Temporal decline in Black sea bass relative abundance across survey periods is attributed to a reduction from 75 fish in fall 2017 to 6 fish in spring 2018 at site HB2, and poor visibility precluded surveying this site in fall 2019. Conversely, 17 Black sea bass were documented from diver video at site HB1 in spring 2018, whereas they were absent at this site in fall 2017; like HB2, diver surveys were not able to be conducted in fall 2019 due to poor visibility.

Baited video recorded six to eight fish species across seasonal survey periods, for a total of 18 fish identifications (and a maximum survey sum of 111 fish) across survey periods (Figure 3b). Only six fish species were common to both baited and diver video: Bank sea bass, Black sea bass, Inshore lizardfish, Longspine porgy, Northern searobin, and Sand perch. Similar to diver video, the sum of maximum survey counts for 15 species (and unidentified finfish) was six or fewer individuals; thus, observations were of limited quantitative value. Black sea bass were observed in all four survey periods, but with reduced observation in 2018 (Figure 3b). Greatest reduction in Black sea bass observations occurred at site HB2, where a maximum of 32 individuals were simultaneously observed in fall 2017 but three or fewer individuals were seen simultaneously in spring and fall 2018. By fall 2019, however, 33 Black sea bass were simultaneously seen at this site, comparable to fall 2017. Palespotted eels were also observed in all four seasonal survey periods, but with one exception of three individuals simultaneously documented, were only seen as one eel per video per site. Throughout the study, Palespotted eels were observed at all but three sites (I8, HB1, HB2); however, temporal trends in presence/absence were inconsistent across sites and survey season.

Temporal Monitoring: Invertebrates

Across seasonal surveys, 50 invertebrate classifications were noted from diver videos (Table 6). Similar numbers of invertebrate classifications were observed in fall 2017 (36) and spring 2018 (32), which comprised 43% and 49% of total invertebrate counts (*n* = 4,093), respectively. Only 11 invertebrate classifications totaling 88 invertebrate counts (2%) were recorded from diver video in fall 2018. By fall 2019, 24 invertebrate classifications were noted in diver video but only comprised 288 invertebrate counts (6%). Invertebrate counts ranged from a single organism (11 classifications) upwards to 2,987 organism counts for *Titanideum* sp. (Table 6).

Seventy-seven percent of invertebrate counts (*n* = 3,777) from diver video were documented at HB1 and HB2 (Figure 4) which were only able to be surveyed in fall 2017 and spring 2018. Fourteen percent of invertebrate counts (*n* = 702) from diver video were documented at I4 which was surveyed in all four seasonal periods. By comparison, four sites (I2, I3, I5, I6) also surveyed in all seasonal periods comprised 327 invertebrate counts (7%), three sites (I1, I8, HB3) surveyed in all but fall 2018 comprised 72 invertebrate counts (2%), and two sites (HB4, I7) only surveyed in fall 2017 and spring 2018 comprised <1% of invertebrate counts (*n* = 25).

Octocorals comprised 68% (*n* = 3,350) of invertebrate counts and occurred at all but I7 and HB4. Among eight sites surveyed in fall 2019, a 48% reduction (from 202 to 106) was noted at site I4, followed by a 64% reduction (from 28 to 10) at site I2; all other temporal shifts were associated with count changes of ≤2 with an initial site count of ≤13. Sponges comprised 24% (*n* = 1,199) of all invertebrate counts but were only seen at seven sites. Among five sponge sites surveyed in fall 2019, a 92% reduction (from 102 to 8) was noted at I4, but only eight sponges were collectively documented across four remaining sites surveyed in fall 2019. For other taxa, ≤13 specimens per species per site were documented during surveys; however, it is notable that 93% (*n* = 7) of Gastropods and 100% (*n* = 37) of worms were not observed until fall 2019.

Twenty-eight invertebrate classifications totaling 169 organism counts were documented from baited video (Table 7). Gray sea stars were the most frequently observed invertebrate and were present in 73% (*n* = 35) of baited video deployments with similar frequency of occurrence and relative abundance across seasonal survey periods (Table 7). Coarsehand lady crabs (*Ovalipes stephensoni*) were observed in 40% (*n* = 19) of baited video deployments with similar frequency of occurrence across seasonal survey periods but greatest relative abundance in spring (Table 7). Flat-clawed hermit crabs (*Pagurus pollicaris*) were seen in 14 (29%) baited video deployments, with the least occurrence (and relative abundance) in spring (Table 7). Remaining invertebrates occurred with ≤11 specimens across baited video surveys (Table 7).

Temporal Monitoring: Acoustic Detections

Acoustic receivers were deployed at three hard bottom sites (HB2, HB3, HB4) and at the two southernmost Inner Boundary zone sites (I6, I5). Acoustic receiver coverage began 22

January 2018 and ended on 3 October 2019 for I6 or on 6 to 16 December 2019 for HB3, HB4, and I5. Daily monitoring coverage was reduced by 48% (of 693 maximum days) at HB2 relative to other hard bottom sites due to loss of the receiver at this location during the final deployment. As such, for analysis, acoustic receiver data were partitioned as before vs. after 17 January 2019, which closely approximates to first and second data collection years for this study.

Two hundred fifty-three transmitters attached to 15 species by 36 research groups (Appendix 1) were detected 6,758 times (Table 8). Across species, 34 transmitters were detected (*n* = 1,001) both before and after 17 January 2019. Two transmitters not identified to species were detected five times (Table 8).

Atlantic sturgeon (*Acipenser oxyrhynchus*) accounted for 42% (*n* = 107) of unique transmitter codes and 47% of total detections (Table 8). Similar numbers of Atlantic sturgeon were detected at HB3, HB4, and I6 across monitoring years, with reduced detection of transmitters at I5 in both years and very few transmitters detected at HB2 in the first monitoring year (Table 8). Conversely, combined sturgeon detections varied inconsistently across sites and years (Table 8).

Cobia (*Rachycentron canadum*) accounted for 13% (*n* = 32) of unique transmitter codes but 27% of total detections (Table 8). Cobia were never detected at HB2 and generally were detected less frequently (i.e., transmitter count and total detections) at two other hard bottom sites than at sites I6 and I5 (Table 8). Cobia detection frequency was greater in 2019 than during 2018 (Table 8); however, 75% of increased detections in 2019 were attributed to a single cobia that was detected >4x more frequently (731) than maximum detection in 2018 (167).

Three shark species (White shark, *Carcharodon carcharias*; Tiger shark, *Galeocerdo cuvier*; Blacktip shark, *Carcharhinus limbatus*) collectively comprised 28% of unique transmitter codes (*n* = 72) but only 19% of total detections (Table 8). Detection trends by monitoring site were inconsistent across years for these species; however, across years, White sharks were generally detected more frequently in the second monitoring year, Tiger shark detection frequency was similar across monitoring years, and Blacktip sharks were detected more frequently in the first monitoring year (Table 8).

Temporal Monitoring: Seafloor Attributes

Diver assessments of the seafloor were conducted during each dive to provide a qualitative characterization of nine seafloor attributes. In fall 2017, three sites (E1, S2, I1) contained a mixture of shell hash and coarse sand and two sites (S5, W7) contained both coarse and fine sand. Among the remaining 37 sites, 54% (20) were solely associated with fine sand, 30% (11) with coarse sand, 14% with silt (5), and only one site was exclusively associated with shell hash. Vertical relief was only documented at nine sites, six with clay balls only, two with rocks/hard bottom, and one with both. Sediment waves were documented at all but seven sites, with 25 sites associated with small waves, eight with large waves, and four with both sediment wave sizes. Manmade marine debris was also noted at eight sites, six of which were located along the western berm arm.

Based on the distribution of nine seafloor attributes, 31 sites were assigned with 100% similarity to one of seven clusters predominantly consisting of two to four sites per cluster that were irrespective of geographical site location within the ODMDS study area (Figure 5). Only four of 12 temporal monitoring sites were not assigned to one of the top seven clusters. Site HB3 was joined with a 90% similarity to site W3 located two km to the east (Figure 5). Site I6 was joined with an 88% similarity to a 13-site cluster that most conspicuously included 70% of southern berm arm sites, but also 20% of eastern and 20% of western berm arm sites as well as two of four temporal monitoring sites in the eastern portion of the ODMDS (Figure 5). Site I7, located in the southwest corner of the ODMDS study area, was joined with an 83% similarity to a four-site cluster comprised of three eastern and a western berm arm site (Figure 5). Lastly, based solely on abiotic seafloor attributes, site I8 located in the northwest corner of the ODMDS study area was joined with a 75% similarity to sites HB1 and HB2 (Figure 5).

Between fall 2017 and spring 2018, qualitative sediment type changed at eight sites (Table 9). Sediment grain size qualitatively increased from coarse sand to a mixture of coarse sand and shell hash at sites HB3 and HB4, and shell hash also became noted at site I4 (Table 9). At HB2, sediment grain size qualitatively shifted from fine to coarse sand; however, at three other sites (I1, I3, I5) sediment type shifted from coarse to fine sand and from fine sand to silt at site I8 (Table 9). In fall 2018, sediment type at site I4 shifted from shell hash and fine sand to exclusively silt, but sediment type remained classified as fine sand at sites I3 and I5 (Table 9). By fall 2019, sediment type reflected initial characterization at two sites classified as fine sand (I4, I8) and two sites classified as coarse sand (I5, HB3); however, site I3 remained characterized by fine sand and no trace of shell hash was noted for site I1 (Table 9). Conversely, no temporal shift in qualitative sediment type was noted between fall 2017 and fall 2019 at three sites initially classified as fine sand (I2, I6, HB1) and a fourth site (I7) classified as silt (Table 9).

No change in relative sand wave height between fall 2017 and fall 2019 was reported for sites I2 through I6 (all characterized by small wave heights) that were surveyed in all four seasonal observation periods; however, in fall 2018, small waves were not noted at I4 (Table 9). At three sites surveyed in all but fall 2018, inconsistent observations were recorded: small waves were absent initially but noted in later surveys at I8; large waves shifted to small waves for the final survey at HB3; and only small waves were noted at I1 whereas both wave heights were noted in previous surveys (Table 9). Hard bottom features were retained at sites I4, HB1, and HB2, and marine debris was only noted at four sites: I6 and HB3 (fall 2017), HB1 and HB4 (spring 2018).

Temporal Monitoring: Sediment Traps and Seafloor Characteristics

Sediment analysis was performed on sediment samples collected by divers at the 11 sampling locations (8 Inner Boundary sites and 3 hard bottom sites) from three time periods for the sediment traps and only the latter two time periods for seafloor sediment samples.

Pooling data across sites indicates that the seafloor sediment was primarily sand and calcium carbonate with a mean across the 11 sites of 98% (minimum-maximum; 96-99%) for both the winter 2019 and fall 2019 periods (Table 10). The mean sand composition across the sites for the winter 2019 was 77% and ranged from 50 to 91% in comparison to the fall 2019 sampling which had a slightly higher mean of 83% and ranged from 69 to 93%. The calcium carbonate percentage was generally highest at the three hard bottom sites, I1, and I5; however, differences between the two sampling periods was evident at several sites (Figure 6). The remaining composition was silt and clay (mean, minimum-maximum; 2%, 1-4%) (Figure 6). This is similar to previous studies with regard to sediment composition in the nearshore (SCDNR 2005). The ratio of silt to clay was overall low with a 0.44 mean and range of 0.1-0.95 and 0.11 mean and range of 0-0.34 for the winter 2019 and fall 2019, respectively.

The seafloor sediment TOM was also similar with a mean of 3.35% (0.92-4.84%) and 3.48% (0.69-7.56%) for the winter 2019 and fall 2019, respectively. In general, the lowest TOM was found at I2 and I4 (Figure 7). The sand grain size (mean sand phi) showed the highest variability among sites with the hard bottom sites being categorized as coarse (low mean sand phi) and the Inner Boundary sites as fine sand (high mean sand phi). The mean sand phi was 1.76 (0-3.05) and 1.87 (0.38-3.06) for the winter 2019 and fall 2019, respectively (Table 10, Figure 7).

In comparison, pooling data across sites indicates that the sediment traps were composed of higher silt and clay content as well as fine mean sand grain sizes than the seafloor sediment. The mean sand and calcium carbonate content was 62%, 57% and 77% for the fa17-sp18, sp18-wi19, and wi19-fa19, respectively, with approximately 75% of the sand and calcium carbonate being the sand fraction (Table 10). The sand content generally showed two patterns – either increasing or similar over time (I1, I3, I5, and I8) and with the lowest sand content during the sp18-wi19 period (Figure 8). The overall higher silt and clay content is expected given the resuspension of finer particles and winnowing of finer particles from the seafloor (SCDNR 2015). The silt and clay content were higher during the fa17-sp18 and sp18-wi19 periods at all but one site (I1) (Figure 8). Some of the highest silt and clay contents were found at I2, I4, I7, and I8. The ratio of silt to clay was found to be similar for the fa17-sp18 and wi19-fa19 period with a slope of 1.3 but the sp18-wi19 period silt to clay ratio slope was 0.3 and overall more variable (i.e., lower R2) (Figure 9).

The sediment trap TOM was generally similar for the three sampling periods with a mean of 11.9% (6.3-18.2%), 10.6% (6.5-17.9%), and 11.2% (7.8-17.1%) for the fa17-sp18, sp18-wi19, and wi19-fa19, respectively. There were no consistent patterns for the TOM (Figure 10). The mean sand grain size (mean sand phi) was always in the fine category with all values above 2.3. This is expected as this is the material that would have been in suspension. In general, the distribution of the sand fractions at the Inner Boundary (except I1 winter 2019 for seafloor sediment) sites across the size classes were similar between the trap sediment and the seafloor sediment. The hard-bottom sites as mentioned above had coarse sand which is evident in the size distribution (Figure 11). The I1 winter 2019 seafloor sand sample distribution showed a higher proportion of medium sand grain size.

The sediment accumulation as measured as the sediment weight gained per area (cm^2) per day was determined. The sediment accumulation varied across the three sampling periods with a mean of 0.145 g/cm^2/day (0.026-0.324 g/cm^2/day), 0.088 g/cm^2/day (0.042-0.133 g/cm^2/day), and 0.122 g/cm^2/day (0.058-0.187 g/cm^2/day) for the fa17-sp18, sp18-wi19, and wi19-fa19, respectively. The highest accumulation occurred in the second time period followed by the first time period. The western half of the sites (I1, I6, I7, I8, HB2, HB3, HB4) were found to have the highest accumulation (except I8 which is close) during the fa17-sp18 period and the lowest levels during the sp18-wi19 period (Figure 10). The eastern sites (I2, I3, I4, I5) had increasing levels across the three sampling periods. The lowest sediment accumulation occurred at the I4 site.

To assess the similarity of samples, sediment characteristics were normalized, a Euclidean distance-based resemblance matrix was generated; and a non-metric Multi-Dimensional Scaling (nMDS) plot was constructed on two different datasets using the statistical analysis software PRIMER, version 7. The first included all the sediment collected for both Job 1 and Job 2 (Figure 12A). The pre-placement sampling via the seafloor young grab and the seafloor sediment scoop samples are overall very similar and distribute to the left of the graph due to the high sand content as evidenced by the sediment composition vectors. The hard-bottom areas and I1 (during one sampling event) have higher calcium carbonate. D1 and D4 are more similar to some of the sediment trap samples. D1 would have been in the footprint of the 1993 placement area while D4 would have been outside of the 1993 placement area. The second analysis included only the sediment trap data (Figure 12B). This analysis generally shows that I2 (sp18-wi19), I4 (fa17-sp18, sp18-wi19), I7 (fa17-sp18, sp18-wi19), and I8 (fa17-sp18) were the most dissimilar from the other samples. This was primarily from finer sand, higher clay or silt and clay, and higher TOM.

Discussion

The value of reliance on multiple data collection techniques to monitor biological responses to active placement of dredge spoil material was reinforced during the present study, which highlighted the challenges of recording visual observations in turbid environments. Active dredging and placement were taking place during this study with hopper and cutterhead suction dredges. The hopper dredges were active in March of 2018 and December 2018 to March 2019 and were placing material along the southern portion of the western berm, southern section of placement zone 1, the southern to eastern berm corner, and the northern portion of the eastern berm. The cutterhead suction dredges were active in April to November 2018 and were placing material along unknown areas and June to November 2019 and placing material along the entire length of the western berm.

Fish and invertebrate species composition and relative abundance were consistently greater in video surveys filmed by scientific divers than by seafloor-facing baited video cameras. Except for spring 2019 when no surveys were attempted, all planned diver surveys were completed at four Inner Boundary Zone sites (I2 through I6) in the eastern half of the ODMDS, and three of four Inner Boundary Zone sites were also surveyed at the end of the study in 2019. Conversely, diver surveys after spring 2018 were only completed at one site (HB3). Survey caveats in mind, temporal change in fish assemblage in the present study was best characterized as a mixed bag. Black sea bass, Longspine porgy, and Tomtate (*Hamulon aurolineatum*) initially declined in observation frequency concurrent with sediment placement in the ODMDS, and due to incomplete diver surveys, it is unclear if these species resumed baseline levels by fall 2019. Alternatively, six reef-associated fish species were not recorded until the end of the study, suggesting at least minimally that habitat value was not lost. With respect to invertebrates, Gray sea stars were most prolific at temporal monitoring sites in fall 2017; however, Atlantic moon snails (*Polinices duplicatus*) and Plumed worms (*Diopatra* sp.) were almost exclusively observed at temporal monitoring sites at the end of the study. Consequently, temporal shifts in fish and invertebrate assemblages were best described as dynamic with no clear change observed.

Remotely collected baited video was particularly valuable in this study because it was the only visual data collection technique that uniformly surveyed all 12 temporal monitoring sites. Baited video was the only observation source for Palespotted eels, the most ubiquitously distributed fish species across survey sites in baited video and the second most ubiquitous fish species across all survey techniques in fall 2017. Palespotted eel sightings in baited video at temporal monitoring were greatest in spring 2018 and fall 2019, suggesting that this species was not adversely impacted by sediment placement activities. Baited video also documented the return of Black sea bass levels to fall 2017 levels in fall 2019, the only source of such data for this species which accounted for most of overall fish abundance in the study area. Lastly, as baited video cameras were retrieved and passed over an unknown expanse of seafloor in fall 2019, the final frames recorded provided qualitative reassurance that sponge and soft coral communities were not drastically altered at two biologically diverse hard bottom sites that were unable to be surveyed by scientific divers after spring 2018.

Acoustic receiver monitoring at a subset of sites located predominantly south of the sediment berm documented 15 large marine species that were virtually absent from visual surveys. Two benthic foragers (Atlantic sturgeon, Cobia) and three large sharks (White, Tiger, Blacktip) were the most frequently detected species in the ODMDS. For all five species, some detected animals were captured and tagged locally by researchers with the SCDNR while others passed through the ODMDS after capture and tagging between Massachusetts and south Florida. Across species, only a small portion of acoustically tagged animals were detected in multiple years; thus, inter-annual variability in detection trends for these species was best explained by outlier events posed by individual transmitters. However, the occurrence of these species in the ODMDS throughout the study demonstrates the lack of extended avoidance concurrent with dredge spoil material placement in the immediate vicinity.

Sediment movement after fall 2017 was apparent through reduced underwater visibility and qualitative seafloor attributes noted by scientific divers, as well as through quantitative data compiled for sediment collection using sediment deposition traps and seafloor point-in-time surface samples. Most changes in sediment attributes were noted early in the study, and for the most part changes persisted through fall 2019 or reverted to fall 2017 characterizations. Although not exclusively, most changes in sediment attributes were associated with increased detection of finer grain material across the 12 temporal monitoring sites.

These observations were generally substantiated by sediment analysis of the traps and seafloor. The seafloor sediment composition was primarily sand and calcium carbonate (>96%) with generally finer sand fractions at Inner Boundary Zone sites and coarser sand fractions at the hard-bottom sites. The hard-bottom sites area was designated SWA in the SCDNR (2005) report which showed similar seafloor sediments to this study. The accumulation in the sediment traps was highest in the spring 2018 to winter 2019 period followed by the fall 2017 to spring 2018 period. The accumulation of sediment was different along the western half of the sites in comparison to the eastern half of the sites. It is unclear if this is due to dredging, placement, or natural sediment transport from the Charleston Harbor plume. Additional spatial location data for dredging and placement would provide more information to determine if the spatial and sampling event patterns were related to sediment dredging and placement.

As expected, based on the results of the SCDNR 2001-2005 monitoring study (SCDNR 2005), sediment accumulation in the sediment traps was of finer materials with higher content of silt and clay as well as finer sand particles. This may be indicative of differences in the natural sediment transport or in relation to where the dredging and placement activities were occurring. The lack of higher silt and clay materials in the seafloor sediment adjacent to the increased levels in the sediment traps indicates that if dredged material is moving across one of the sampling sites that there is no retention of the silt and clay at these sites on the seafloor.

Figures

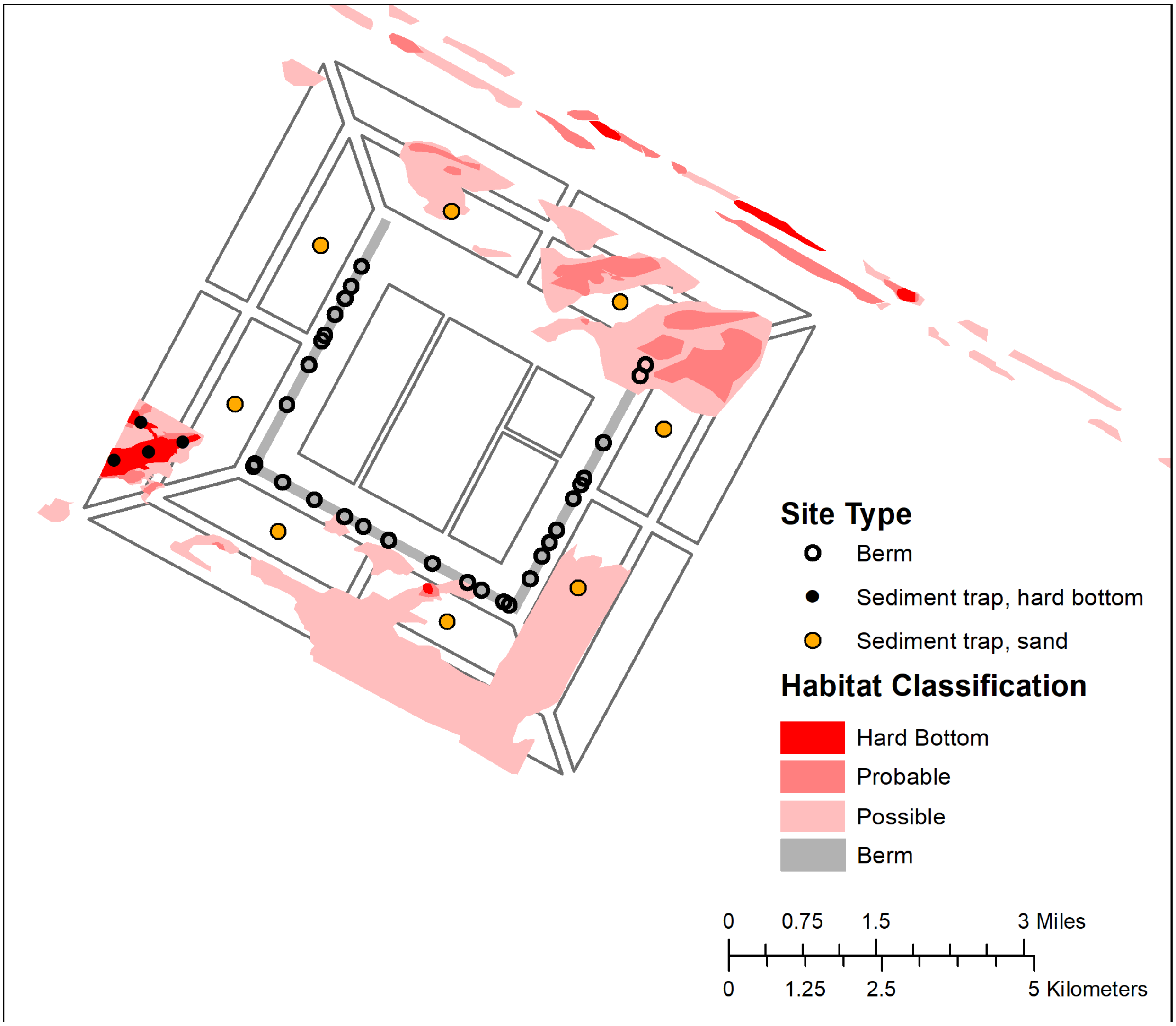


Figure 1. Ten randomly selected dive sites (open circle) were chosen for pre-construction characterization of habitat features in each of the proposed berm (gray) arms located along the perimeter of the authorized disposal zone. Eight temporal reference sites (orange circle) were selected as the central coordinates for each of the Inner Boundary (I1 through I8) zones. Four additional temporal monitoring sites (filled circles) were also established in a historically hard bottom area (red) located predominantly in the southwest corner of Outer Boundary zone O7.

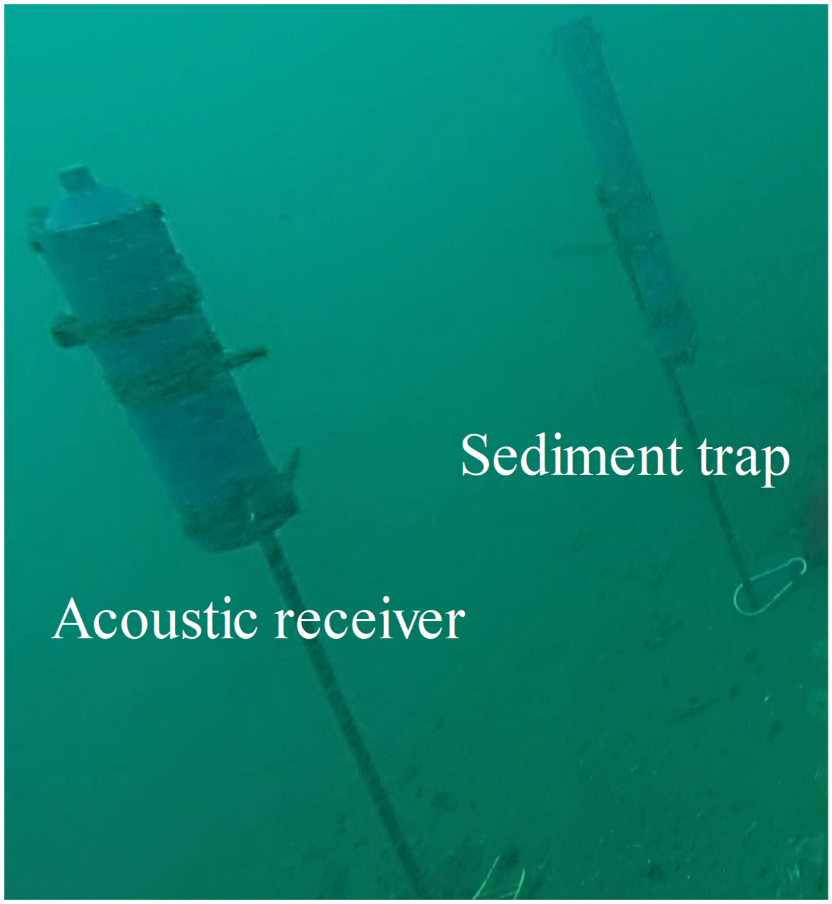


Figure 2. Acoustic receivers and sediment traps were secured to screw anchors and rebar stakes and positioned 0.6 m above the seafloor and in relative proximity to each other.

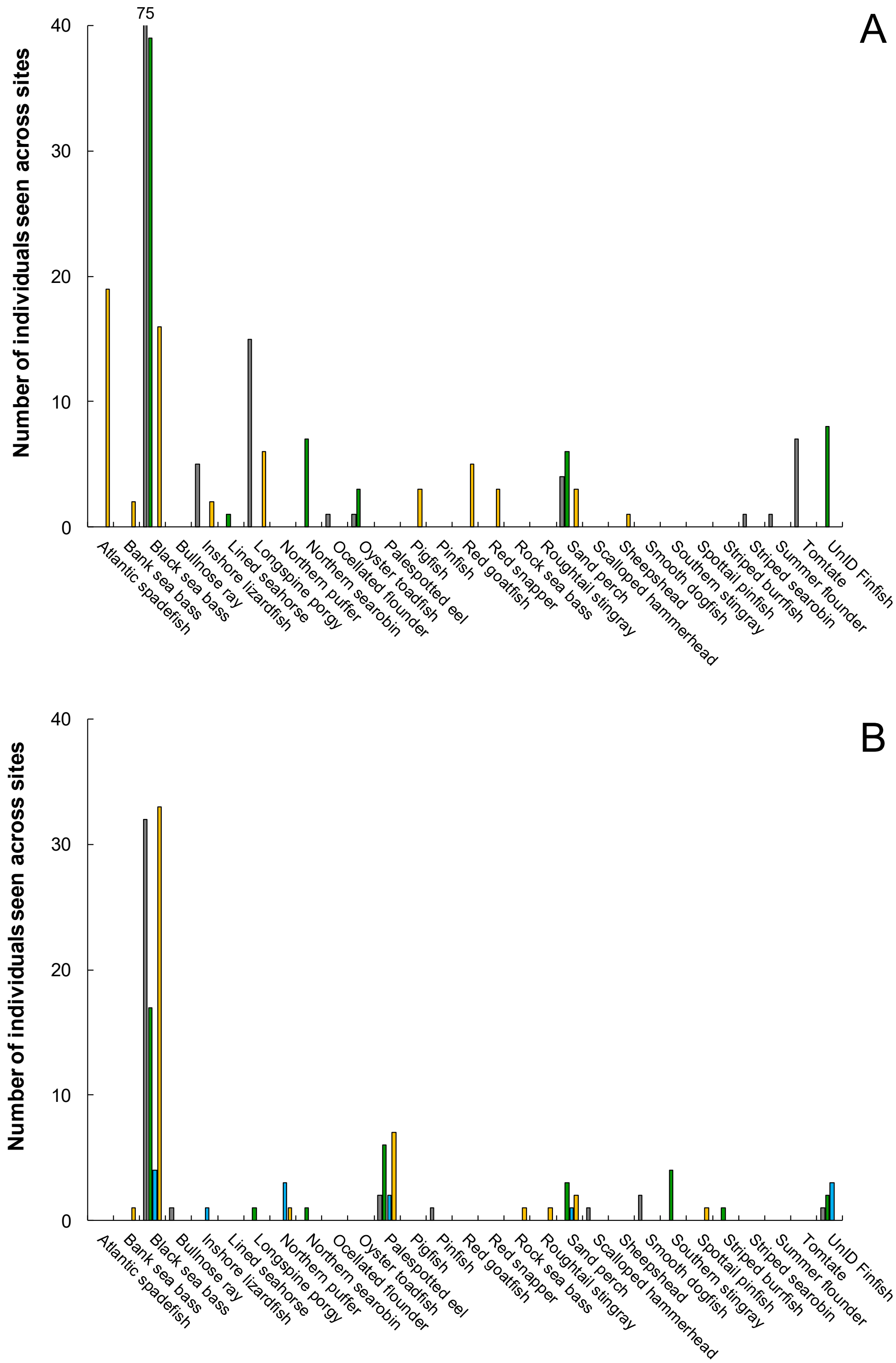


Figure 3. Relative observation of 22 fish species (plus unidentified finfish) seen in diver (A) and baited video (B) with respect to four seasonal survey periods: fall 2017 (gray); spring 2018 (green); fall 2018 (blue); and fall 2019 (yellow).

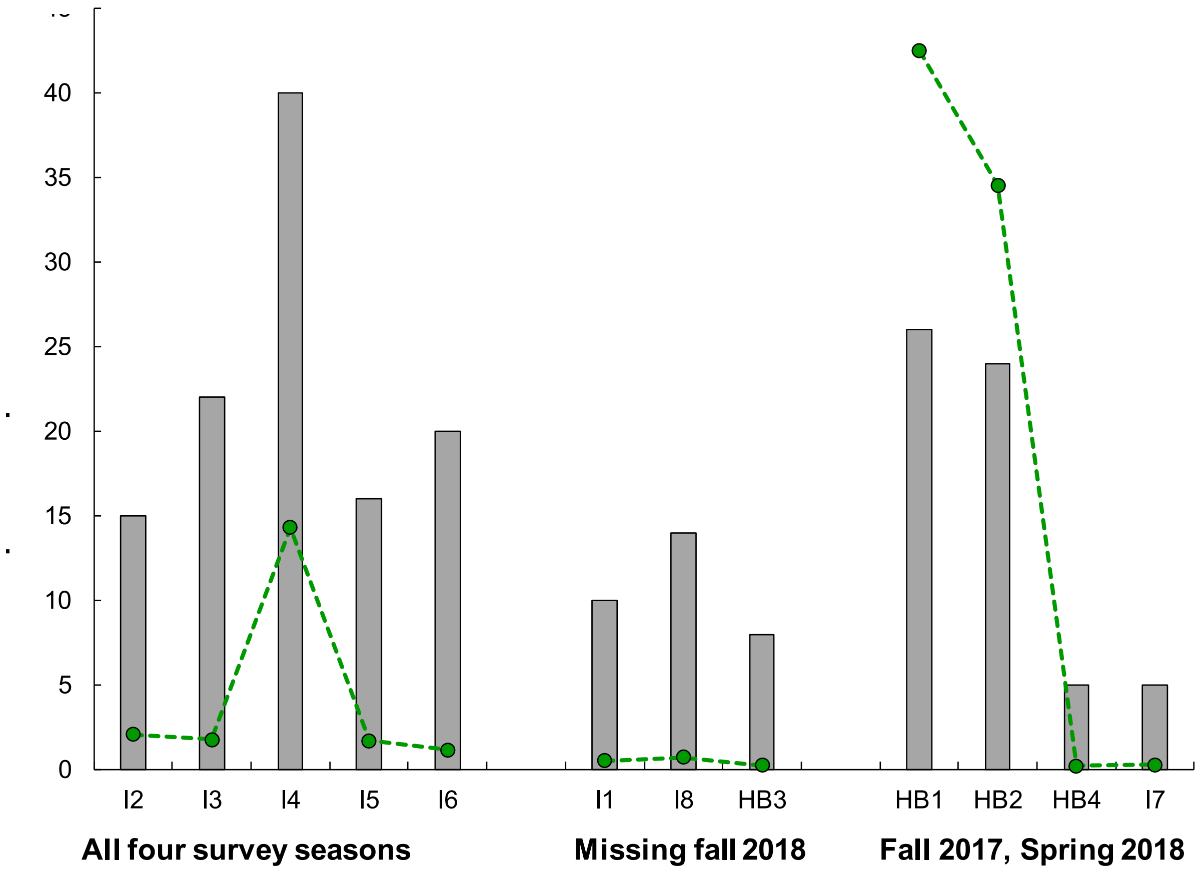


Figure 4. Number of invertebrate species (gray bar) or percent relative abundance (green series) observed across five temporal monitoring sites surveyed four times (left grouping), three temporal monitoring sites surveyed three times including fall 2019 (center grouping), or four temporal monitoring sites surveyed three times but only through fall 2018 only (right grouping).

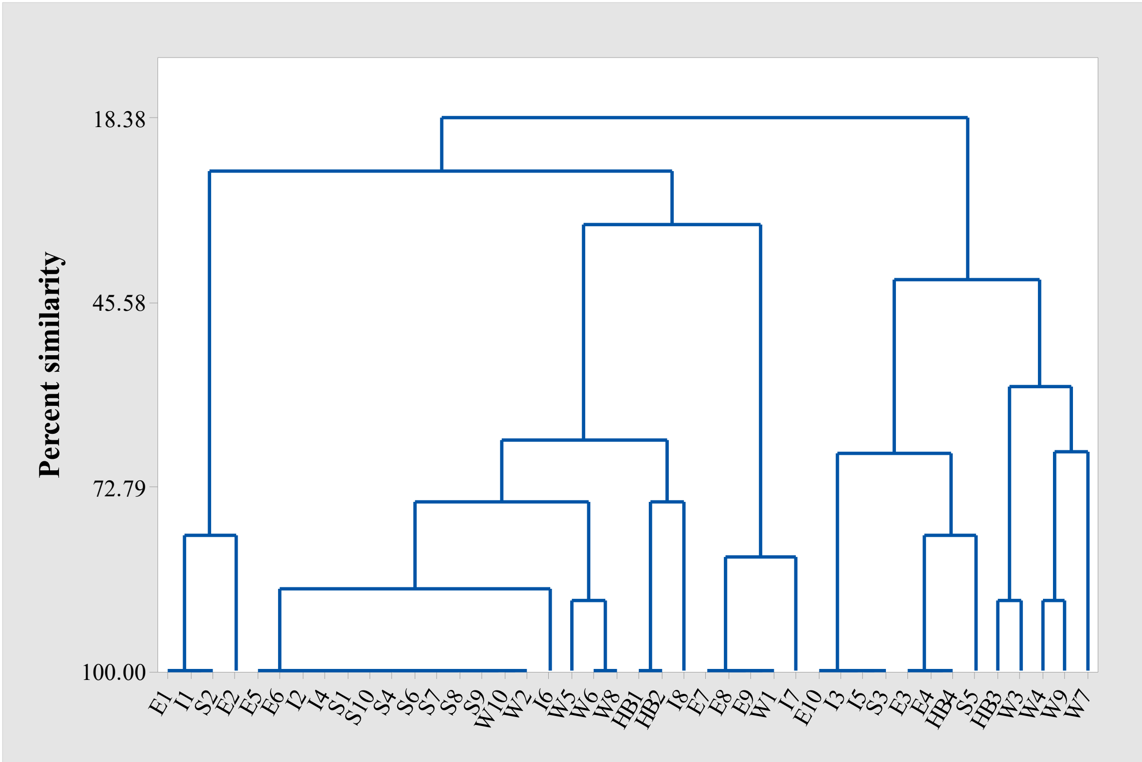
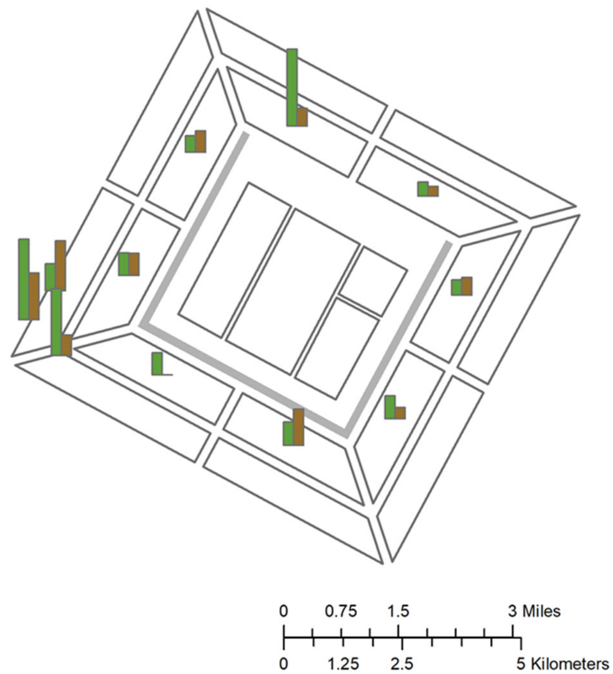


Figure 5. Dendrogram depicting relatedness (percent similarity, y-axis) among 42 sites (x-axis) surveyed in fall 2017 with respect to presence (1) or absence (0) scores across four sediment types (shell hash, coarse sand, fine sand, silt), two vertical relief features (rocks or other hard bottom, clay balls), sand waves (small vs. large), or any form of manmade marine debris.

A



B

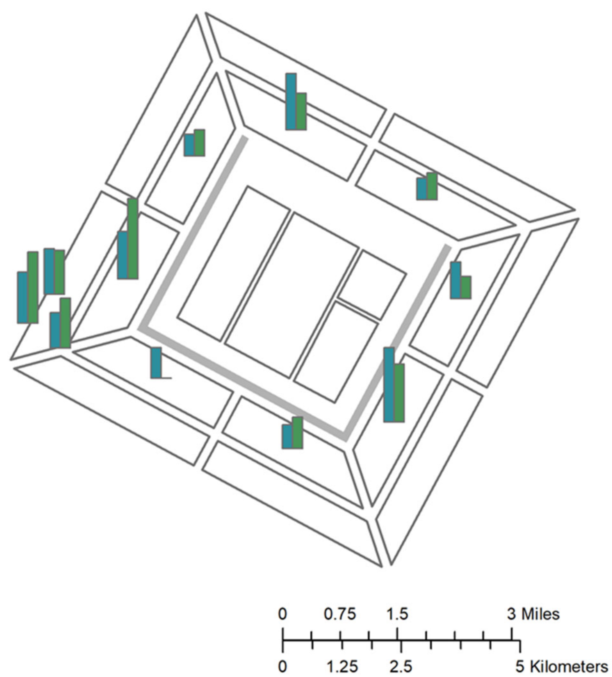
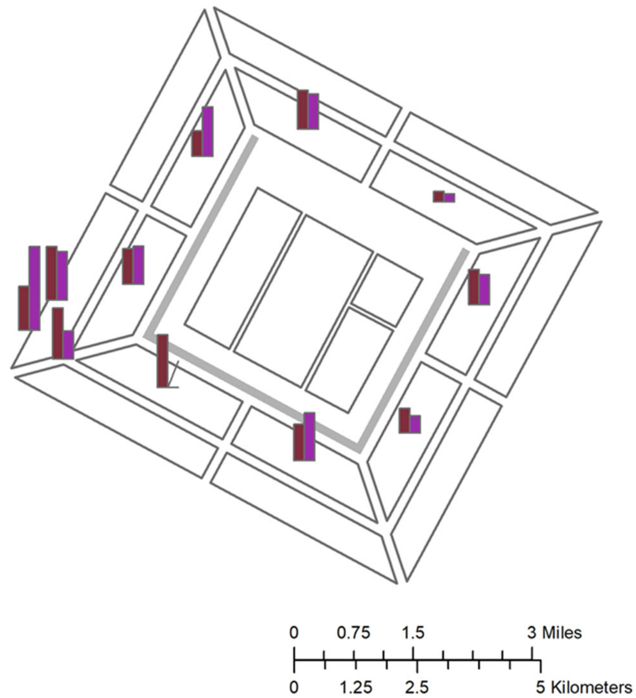


Figure 6. Seafloor content of calcium carbonate (maximum bar height = 47.22%; A) and silt/clay (maximum bar height = 4.02%; B) observed across eleven temporal monitoring sites surveyed in the winter 2019 (left bar) and fall 2019 (right bar).

A



B

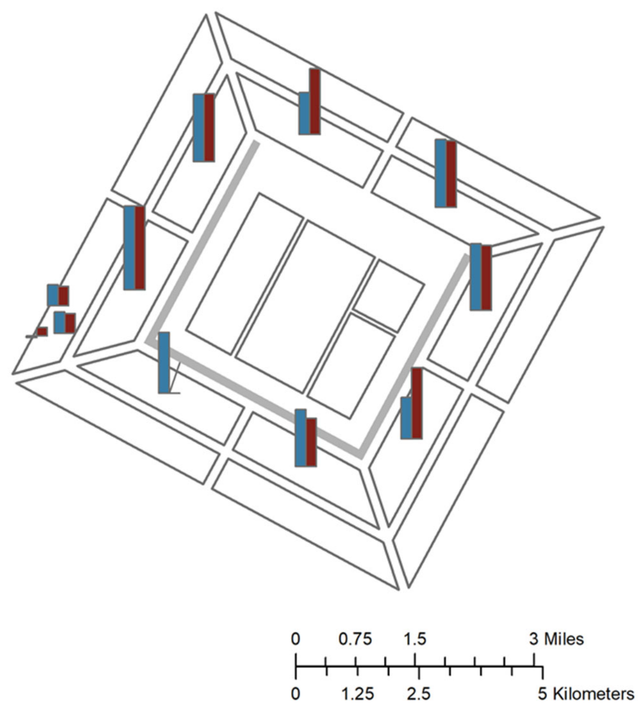
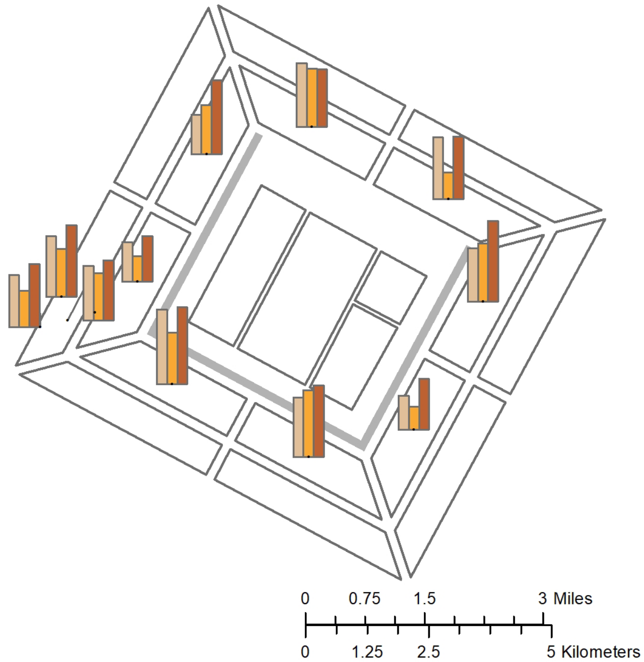


Figure 7. Seafloor content of TOM (maximum bar height = 7.56%; A) and sand grain size (maximum bar height = 3.06; B) observed across eleven temporal monitoring sites surveyed in the winter 2019 (left bar) and fall 2019 (right bar).

A



B

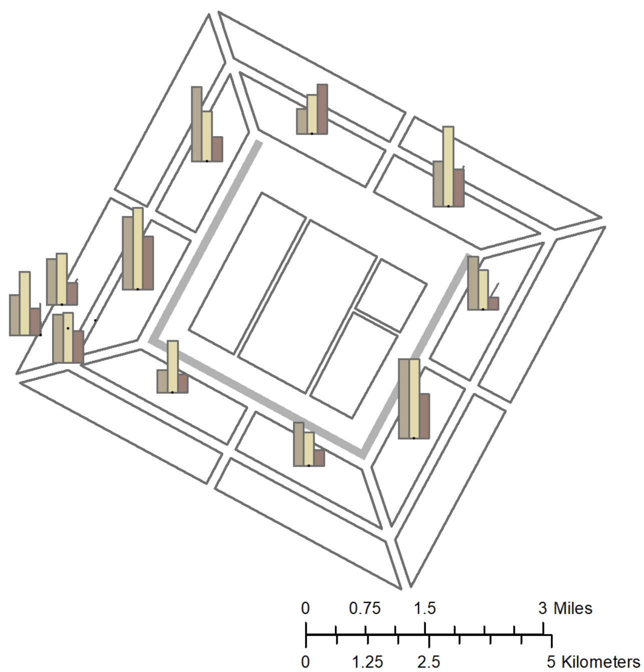


Figure 8. Sediment trap content of sand (maximum bar height = 74.7%; A) and silt and clay (maximum bar height = 61.5%; B) observed across eleven temporal monitoring sites surveyed in the fa17-sp18 (left bar), sp18-wi19 (middle bar), and wi19-fa19 (right bar).

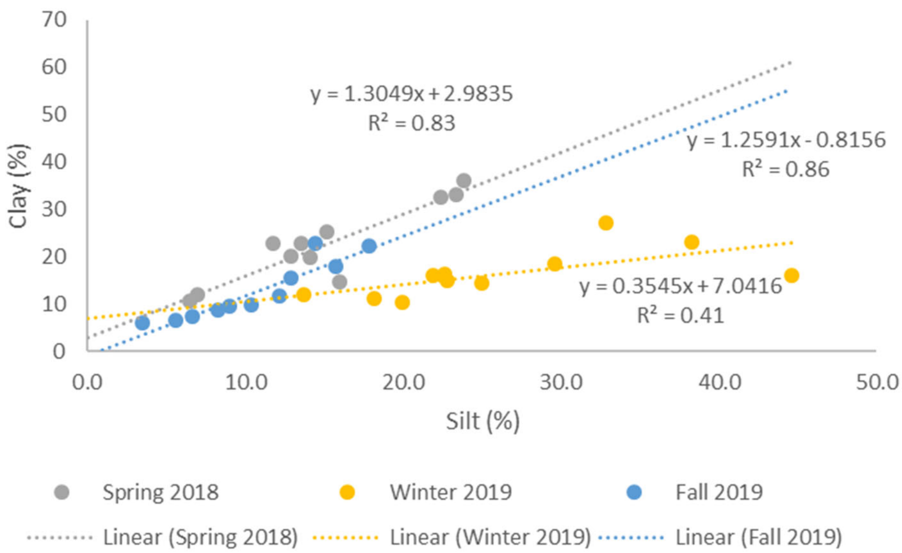
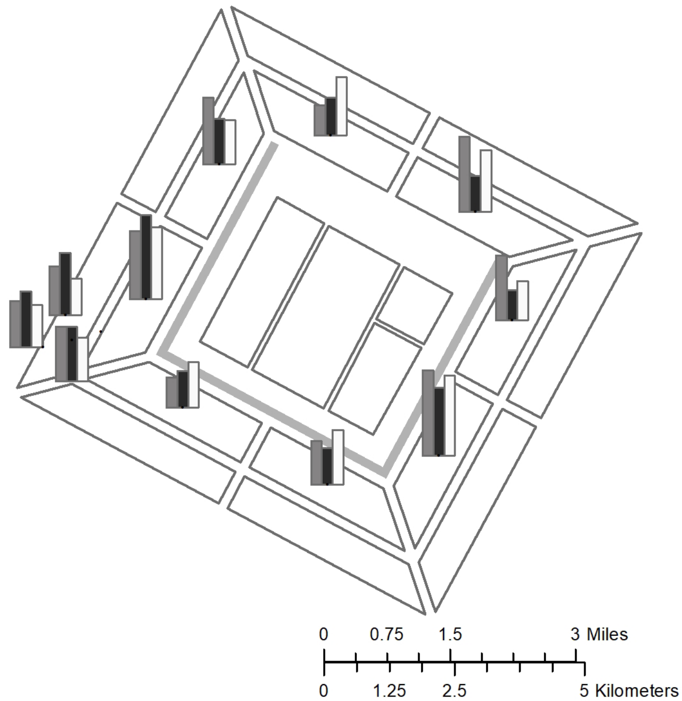


Figure 9. Sediment trap content of silt (%) versus clay (%) for the three sampling periods with regressions lines for each period.

A



B

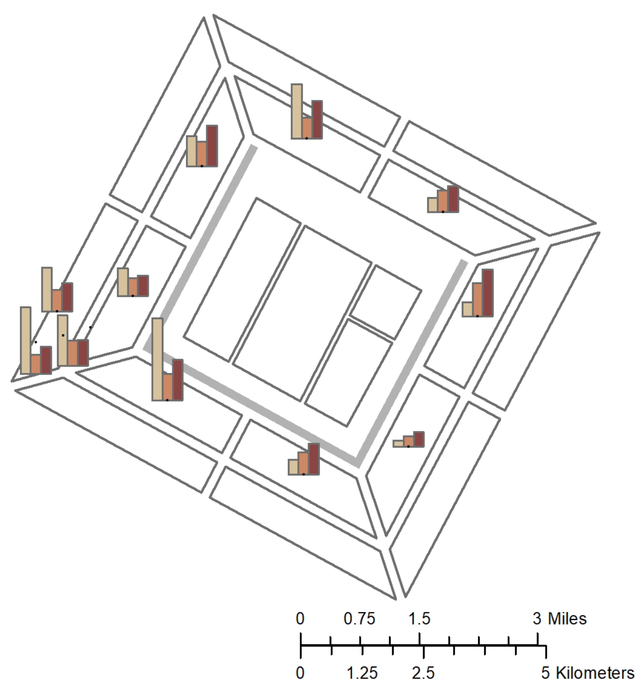


Figure 10. Sediment trap content of TOM (maximum bar height =18.2%; A) and weight (maximum bar height = 0.324 g/cm^2/day; B) observed across eleven temporal monitoring sites surveyed in the fa17-sp18 (left bar), sp18-wi19 (middle bar), and wi19-fa19 (right bar).

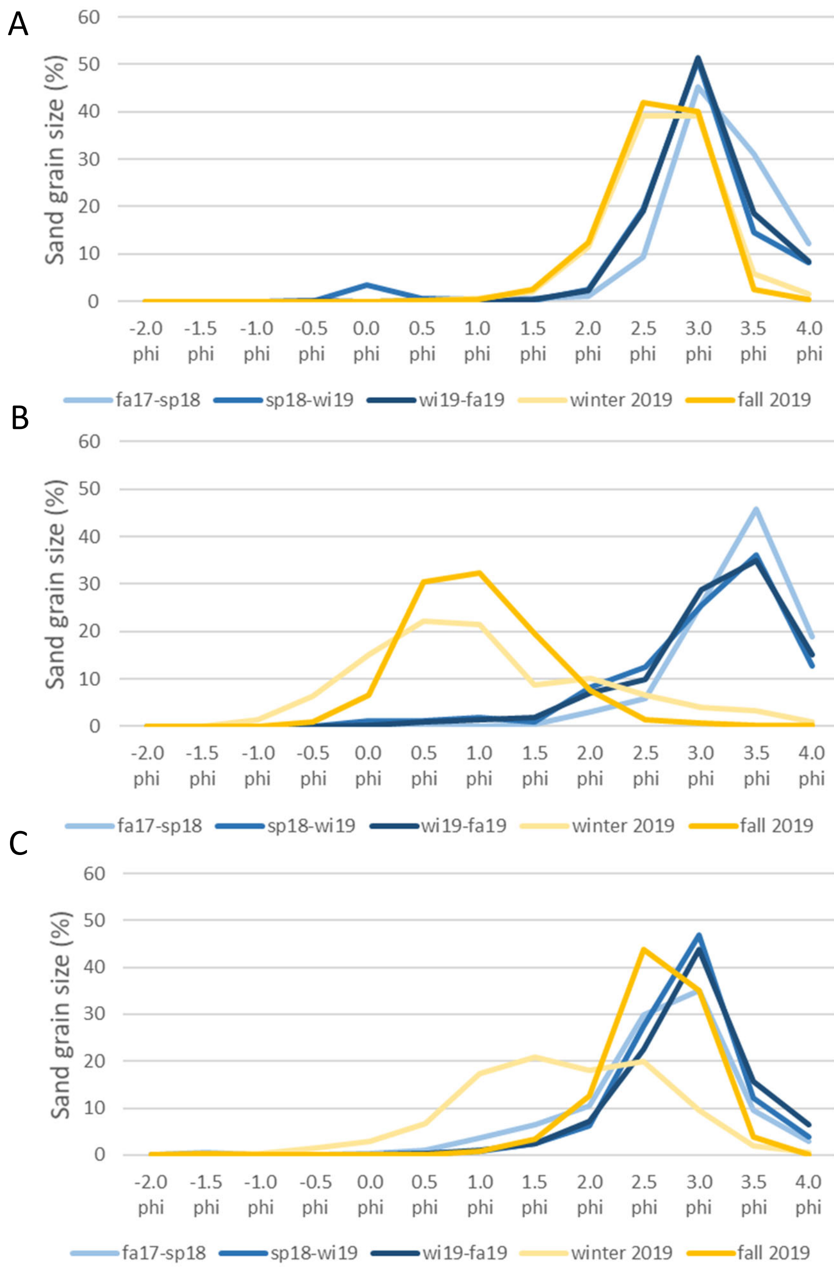


Figure 11. Sand grain size distributions for the sediment trap and seafloor sediment samples. Three representative sites are presented:(A) I2 – primarily fine grain sediments, (B) HB2 0 sediment trap fine grain and seafloor coarse to medium, and (C) I1 – spring 2018 seafloor sample different than the others.

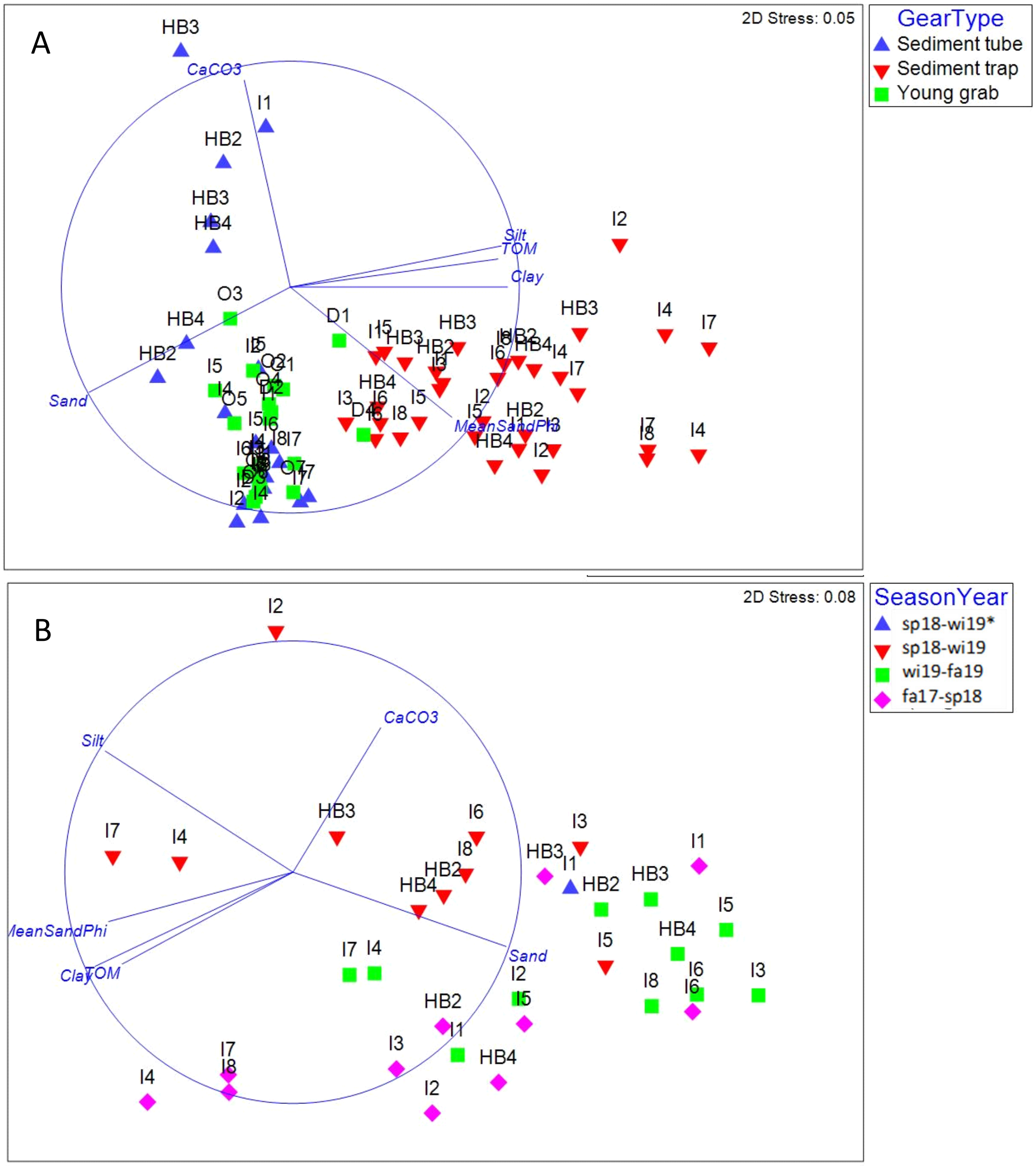


Figure 12. The nMDS plot for average sediment samples from Job 1 and all sediment samples and sediment trap samples (A) and only sediment trap samples (B). Vectors for the various parameters are overlaid on the plot to show the spatial influence of the various parameters. *I1 was sampled later than the other sediment traps but is still considered part of the sp18-wi19 sampling period.

Tables

Table 1. Wave height and sediment codes used to characterize seafloor features at survey sites.

Code	Description
WZ001	Sand wave, small (<6" amplitude)
WZ002	Sand wave, large (>6" amplitude)
ZZ003	Shell hash
ZZ004	Coarse sand
ZZ005	Fine sand
ZZ006	Silt
ZZ007	Clay and/or clay balls
ZZ008	Rocks and/or hard bottom
ZZ009	Marine debris

Table 2. Frequency of sharks, rays, and finfish (ordered alphabetically by common name) during diver and baited video surveys (29 November 2017 to 22 January 2018). Cell values denote the number of surveys recorded for each of three berm arms (West, South, East), Inner Boundary zone monitoring sites, and Hard Bottom (HB) monitoring sites.

		# of diver video surveys						# of baited video surveys					
Common Name	Scientific Name	West	South	East	Inner	HB	*Total*	West	South	East	Inner	HB	*Total*
Scalloped hammerhead	*Sphyrna lewini*						*0*	1			1		*2*
Smooth dogfish	*Mustelus canis*						*0*					2	*2*
Bullnose ray	*Myliobatis freminvillei*		1				*1*	2	4		1		*7*
Roughtail stingray	*Dasyatis centroura*						*0*		1				*1*
Southern stingray	*Dasyatis americana*		1				*1*		1				*1*
Dwarf sand perch	*Diplectrum bivittatum*	2					*2*						*0*
Bank sea bass	*Centropristis ocyurus*		1				*1*						*0*
Black sea bass	*Centropristis striata*	3				1	*4*	4	1			1	*6*
Inshore lizardfish	*Synotus foetens*	2	4	4	4		*14*						*0*
Leopard searobin	*Prionotus scitulus*	2					*2*						*0*
Longspine porgy	*Stenotomus aculeatus*	1			1		*2*						*0*
Northern puffer	*Sphoeroides maculatus*						*0*	1	1				*2*
Ocellated flounder	*Ancylopsetta quadrocellata*				1		*1*						*0*
Oyster toadfish	*Opsanus tau*				1		*1*						*0*
Palespotted eel	*Ophichthus ocellatus*						*0*	1	5	4	2		*12*
Pearly razorfish	*Hemipteronotus novacula*			1			*1*						*0*
Pinfish	*Lagodon rhomboides*						*0*				1		*1*
Sand perch	*Diplectrum formosum*	6	1		1		*8*	3	2	1			*6*
Spotted whiff	*Citharichthys macrops*		1				*1*						*0*
Striped searobin	*Prionotus evolans*				1		*1*						*0*
Summer flounder	*Paralichthys dentatus*	1			1		*2*						*0*
Tomtate	*Haemulon aurolineatum*				1		*1*		1	1			*2*
UnID Lefteye Flounder	Bothidae		2				*2*						*0*
UnID Finfish	Osteichthyes	1		2			*3*		1	2	1		*4*

Table 3. Relative counts of sharks, rays, and finfish (ordered alphabetically by common name) during diver and baited video surveys (29 November 2017 to 22 January 2018). For diver surveys, cell values denote the sum of all video observations recorded for each of three berm arms (West, South, East), Inner Boundary zone monitoring sites, and Hard Bottom (HB) monitoring sites. For baited video, cell values denote the sum of maximum species counts recorded for each survey conducted in each of the berm and temporal monitoring areas.

		Sum across diver surveys						Sum of max counts, baited video					
Common Name	Scientific Name	West	South	East	Inner	HB	*Total*	West	South	East	Inner	HB	*Total*
Scalloped hammerhead	*Sphyrna lewini*						*0*	1			1		*2*
Smooth dogfish	*Mustelus canis*						*0*					2	*2*
Bullnose ray	*Myliobatis freminvillei*		1				*1*	2	4		1		*7*
Roughtail stingray	*Dasyatis centroura*						*0*		1				*1*
Southern stingray	*Dasyatis americana*		1				*1*		1				*1*
Dwarf sand perch	*Diplectrum bivittatum*	2					*2*						*0*
Bank sea bass	*Centropristis ocyurus*		1				*1*						*0*
Black sea bass	*Centropristis striata*	109				75	*184*	101	1			32	*134*
Inshore lizardfish	*Synotus foetens*	2	4	5	5		*16*						*0*
Leopard searobin	*Prionotus scitulus*	2					*2*						*0*
Longspine porgy	*Stenotomus aculeatus*	10			15		*25*						*0*
Northern puffer	*Sphoeroides maculatus*						*0*	1	1				*2*
Ocellated flounder	*Ancylopsetta quadrocellata*				1		*1*						*0*
Oyster toadfish	*Opsanus tau*				1		*1*						*0*
Palespotted eel	*Ophichthus ocellatus*						*0*	1	5	5	2		*13*
Pearly razorfish	*Hemipteronotus novacula*			1			*1*						*0*
Pinfish	*Lagodon rhomboides*						*0*				1		*1*
Sand perch	*Diplectrum formosum*	14	1		4		*19*	4	2	2			*8*
Spotted whiff	*Citharichthys macrops*		1				*1*						*0*
Striped searobin	*Prionotus evolans*				1		*1*						*0*
Summer flounder	*Paralichthys dentatus*	1			1		*2*						*0*
Tomtate	*Haemulon aurolineatum*				7		*7*		1	2			*3*
UnID Lefteye Flounder	Bothidae		2				*2*						*0*
UnID Finfish	Osteichthyes	1		3			*4*		1	2	1		*4*

Table 4. Relative occurrence and invertebrates (ordered by taxa then by common name) during diver and baited video surveys (29 November 2017 to 22 January 2018). For diver and baited video surveys, cell values denote counts of sites or sums of organisms within survey areas. For baited video, values in parentheses distinguish species seen with more than one organism, and cell values reflect the sum of organisms observed (and number of surveys where present).

		# of diver video sites observed						# of diver video organisms observed						# of baited video organisms (sites)					
Common Name	Scientific Name	W	S	E	I	H	*Total*	W	S	E	I	H	*Total*	W	S	E	I	H	*Total*
Pink sea pork	*Aplidium stellatum*					1	*1*					10	*10*						
UnID sea pork	*Aplidium* sp.	1			1		*2*	1			2		*3*						
Sea liver	*Eudistoma hepaticum*	2	1	1		1	*5*	5	1	1		1	*8*						
Barrel sponge	*Ircinia* sp.					1	*1*					1	*1*						
Finger sponge	*Haliclona* sp.				1	2	*3*				40	308	*348*						
Golfball sponge	*Cinachyra alloclada*					1	*1*					3	*3*						
Redbeard sponge	*Microciona prolifera*	3					*3*	6					*6*						
Sulphur sponge	*Cliona celata*	2	1	1	0	3	*7*	2	1	1		55	*59*						
UnID Sponge	Porifera			1	1	2	*4*			1	62	131	*194*						
White crown sponge	*Ciocalapata gibbsi*					1	*1*					1	*1*						
Yellow crown sponge	*Raspailia* sp.					1	*1*					1	*1*						
Yellowfan sponge	*Axinella* sp.					2	*2*					19	*19*						
Coarsehand lady crab	*Ovalipes stephensoni*						*0*							1	9 (7)	8	5	1	*24*
Flat-clawed hermit crab	*Pagurus pollicaris*				3		*3*				3		*3*				3	6 (2)	*9*
Hairy mud crab	*Pilumnus* sp.						*0*									1			*1*
Horseshoe crab	*Limulus polyphemus*	3	2	1		1	*7*	4	2	1		1	*8*						*0*
Irridescent swimming crab	*Portunus gibbesii*						*0*									2	3		*5*
Lesser blue crab	*Callinectes similis*		1	1			*2*		1	1			*2*	2	4	2 (1)			*8*
Mottled swimming crab	*Portunus spinimanus*						*0*							3	9	10 (7)	2		*24*
Purse crab	*Persephona mediterranea*			1			*1*			1			*1*						*0*
Red hermit crab	*Petrochirus diogenes*				1		*1*				1		*1*						*0*
Shamefaced crab	*Calappa flammea*						*0*										1		*1*
Speckled crab	*Arenaeus cribrarius*						*0*									3	1		*4*
Speckled lady crab	*Ovalipes ocellatus*						*0*							1					*1*
Star coral	*Astrangia danae*	1					*1*	1					*1*						*0*
Sea pen	*Virgularia presbytes*		7	5	3		*15*		23	27	24		*74*				1		*1*
Sea whip	*Leptogorgia virgulata*	8	8	8	6	2	*32*	17	17	34	62	44	*174*						*0*
Sea Whip/Sea fan	*Leptogorgia* sp.				1	1	*2*				6	12	*18*						*0*
Sea finger	*Titanideum* sp.				1	2	*3*				153	1098	*1251*						*0*
UnID Octocoral	*Octocorallia*				1		*1*				6		*6*						*0*
Anemone	*Anemonia sargassensis*		3	4	3	1	*11*		3	5	6	1	*15*				1	1	*2*
Box jellyfish	Cubozoa		1				*1*		1				*1*						*0*
UnID Actinarian	Actiniaria	1					*1*	1					*1*						*0*
UnID Hydroid	Hydroidea	5			1	1	*7*	9			10	4	*23*						*0*
Common sea star	*Asterias forbesii*	1			1		*2*	1			4		*5*						*0*
Gray sea star	*Luidia clathrata*	1	9	9	8	1	*28*	6	22	22	33	5	*88*	6 (4)	12 (10)	8	10 (8)	2	*28*
Green brittle star	*Ophioderma brevispinum*				1		*1*				1		*1*					1	*1*
Margined sea star	*Astropecten articulatus*		1	5		1	*7*		1	7		1	*9*			1	2		*3*
Purple urchin	*Arbacia punctulata*				1		*1*				1		*1*						*0*
Sand dollar	*Mellita sexiesperforata*					1	*1*					1	*1*						*0*
Spiny sea star	*Echinaster* sp.	1				1	*2*	1				2	*3*						*0*
Two-spined sea star	*Astropecten duplicatus*		3	1	3		*7*		4	1	6		*11*	1	2	1		1	*5*
Atlantic moon snail	*Polinices duplicatus*					1	*1*					1	*1*						*0*
Brief squid	*Lolliguncula brevis*		1				*1*		1				*1*						*0*
Common octopus	*Octopus vulgaris*				1		*1*				1		*1*	1					*1*
Helmet conch	*Cassis madagascariensis*				1		*1*				1		*1*						*0*
Nudibranch	*Nudibranchia*				1		*1*				1		*1*				1	1	*2*
Olive cowery	*Oliva sayana*				1		*1*				1		*1*	1	2	2	3		*8*
Staghorn bryozoan	*Schizoporella floridana*	1				1	*2*	1				1	*2*						
Red algae	*Rhodophyta*				1		*1*				2		*2*						
Sea lettuce	*Ulva lactuca*	1					*1*	1					*1*						

Table 5. Overview of video data collection at temporal monitoring sites, fall 2017 to fall 2019. Neither diver nor baited video surveys were completed in spring 2019 due to logistical emphasis on establishing survey sites for a companion USACE-funded study.

Site	Fa '17	Sp '18	Fa '18	Sp '19	Fa '19
I1	x	x			x
I2	x	x	x		x
I3	x	x	x		x
I4	x	x	x		x
I5	x	x	x		x
I6	x	x	x		x
I7	x	x			
I8	x	x			x
HB1	x	x			
HB2	x	x			
HB3	x	x			x
HB4	x	x			

Table 6. Temporal distribution in the relative abundance of 50 invertebrate classifications documented from diver video across ODMDS sites through fall 2019. Taxonomic categories are ordered from most to least primitive, then by most to least abundant within categories.

Category	Common Name	Scientific Name	Fall '17	Spring '18	Fall '18	Fall '19	*Total*
Chordate	Pink sea pork	*Aplidium stellatum*	10	9	1	1	*21*
Chordate	UnID sea pork	*Aplidium* sp.	2	1		1	*4*
Chordate	Sea liver	*Eudistoma hepaticum*	1	1			*2*
Sponge	Finger sponge	*Haliclona* sp.	348	298		3	*649*
Sponge	UnID Sponge	Porifera	193	61		6	*260*
Sponge	Sulphur sponge	*Cliona celata*	55	33	1	6	*95*
Sponge	White crown sponge	*Ciocalapata gibbsi*	1	58			*59*
Sponge	Yellow crown sponge	*Raspailia* sp.	1	57			*58*
Sponge	Golfball sponge	*Cinachyra alloclada*	3	40			*43*
Sponge	Yellowfan sponge	*Axinella* sp.	19	15			*34*
Sponge	Barrel sponge	*Ircinia* sp.	1				*1*
Crustacean	Flat-clawed hermit crab	*Pagurus pollicaris*	3			1	*4*
Crustacean	Coarsehand lady crab	*Ovalipes stephensoni*		3			*3*
Horseshoe crab	Horseshoe crab	*Limulus polyphemus*	1	1		1	*3*
Crustacean	Shamefaced crab	*Calappa flammea*		1		1	*2*
Crustacean	Calico crab	*Hepatus epheliticus*		2			*2*
Crustacean	Arrow crab	*Stenorhynchus seticornis*		1			*1*
Crustacean	Mottled swimming crab	*Portunus spinimanus*				1	*1*
Crustacean	Red hermit crab	*Petrochirus diogenes*	1				*1*
Octocoral	Titanideum	*Titanideum* sp.	1,251	1,617	39	80	*2,987*
Octocoral	Sea whip	*Leptogorgia virgulata*	106	59	31	22	*218*
Octocoral	Sea pen	*Virgularia presbytes*	24	38	3	11	*76*
Octocoral	Sea Whip/Sea fan	*Leptogorgia* sp.	18	36	3	4	*61*
Other Cnidarian	UnID Hydroid	Hydroidea	14	14		23	*51*
Other Cnidarian	Anemone	*Anemonia sargassensis*	7	5	1		*13*
Octocoral	UnID Octocoral	Octocorallia	6				*6*
Other Cnidarian	UnID Actinarian	Actiniaria				5	*5*
Octocoral	Telesto	*Telesto fruticulosa*				2	*2*
Hard coral	Hard coral			1			*1*
Echinoderm	Gray sea star	*Luidia clathrata*	38	14	1	18	*71*
Echinoderm	Two-spined sea star	*Astropecten duplicatus*	6	6			*12*
Echinoderm	Common sea star	*Asterias forbesii*	4	2	3		*9*
Echinoderm	Margined sea star	*Astropecten articulatus*	1	2	3	2	*8*
Echinoderm	Purple urchin	*Arbacia punctulata*	1	2	2		*5*
Echinoderm	Spiny sea star	*Echinaster* sp.	2				*2*
Echinoderm	Sand dollar	*Mellita sexiesperforata*	1	1			*2*
Echinoderm	Banded starfish	*Luidia alternata*				1	*1*
Echinoderm	Green brittle star	*Ophioderma brevispinum*	1				*1*
Gastropod	Atlantic moon snail	*Polinices duplicatus*	1			68	*69*
Gastropod	Atlantic jacknife clam	*Ensis directus*				2	*2*
Gastropod	Olive cowery	*Oliva sayana*	1	1			*2*
Gastropod	Channeled whelk	*Busycon canaliculata*				1	*1*
Cephalopod	Common octopus	*Octopus vulgaris*	1				*1*
Gastropod	Helmet conch	*Cassis madagascariensis*	1				*1*
Nudibranch	Nudibranch	*Nudibranchia*	1				*1*
Worm	Plumed worm	*Diopatra* sp.				37	*37*
Bryozoan	Rubbery bryozoan	*Alcyonidium hauffi*		5		1	*6*
Bryozoan	Staghorn bryozoan	*Schizoporella floridana*	1	1			*2*
Vegetation	UnID Algae			5			*5*
Vegetation	Red algae	Rhodophyta	2				*2*
		N species	*36*	*32*	*11*	*24*	*50*
		Sum	*2,127*	*2,390*	*88*	*298*	*4,903*

Table 7. Temporal occurrence and relative abundance of 28 invertebrate classifications documented from baited video across ODMDS sites through fall 2019. Taxonomic categories are ordered from most to least primitive, then by most to least abundant within categories, where relative abundance is the sum of maximum simultaneous counts per site survey.

			Number of surveys observed					Relative abundance observed				
Category	Common Name	*Scientific Name*	Fall '17	Spring '18	Fall '18	Fall '19	*Total*	Fall '17	Spring '18	Fall '18	Fall '19	*Total*
Sponge	UnID Sponge	Porifera				1	1				1	1
Crustacean	Coarsehand lady crab	*Ovalipes stephensoni*	6	5	4	4	19	6	11	4	4	25
Crustacean	Flat-clawed hermit crab	*Pagurus pollicaris*	5	1	5	3	14	9	1	6	3	19
Crustacean	Mottled swimming crab	*Portunus spinimanus*	2	6		1	9	2	8		1	11
Crustacean	Irridescent swimming crab	*Portunus gibbesii*	3	3	1	2	9	3	4	1	2	10
Crustacean	UnID Crab	Decapoda				3	3				3	3
Crustacean	Shamefaced crab	*Calappa flammea*	1	1			2	1	1			2
Crustacean	Calico crab	*Hepatus epheliticus*		1		1	2		1		1	2
Crustacean	Striped hermit crab	*Clibanarius vittatus*				1	1				1	1
Crustacean	Speckled lady crab	*Ovalipes ocellatus*			1		1			1		1
Crustacean	Speckled crab	*Arenaeus cribrarius*	1				1	1				1
Crustacean	Spider crab	*Libinia dubia*		1			1		1			1
Octocoral	Titanideum	*Titanideum* sp.		1	1	1	3		1	6	12	19
Other Cnidarian	Anemone	*Anemonia sargassensis*	2				2	2				2
Other Cnidarian	UnID Actinarian	Actiniaria				2	2				2	2
Octocoral	Sea whip	*Leptogorgia virgulata*			1		1			1		1
Octocoral	Sea Whip/Sea fan	*Leptogorgia* sp.		1			1		1			1
Octocoral	Sea pen	*Virgularia presbytes*	1				1	1				1
Other Cnidarian	UnID Hydroid	Hydroidea				1	1				1	1
Echinoderm	Gray sea star	*Luidia clathrata*	10	7	9	9	35	12	13	10	12	47
Echinoderm	Margined sea star	*Astropecten articulatus*	2		1		3	2		1		3
Echinoderm	Two-spined sea star	*Astropecten duplicatus*	1		1		2	1		1		2
Echinoderm	Green brittle star	*Ophioderma brevispinum*	1				1	1				1
Gastropod	Olive cowery	*Oliva sayana*	3		1	1	5	3		1	1	5
Gastropod	Nudibranch	Nudibranchia	2				2	2				2
Gastropod	Pear whelk	*Busycon spiratum*		1			1		1			1
Gastropod	Atlantic jacknife clam	*Ensis directus*				1	1				1	1
Worm	UnID scale worm	Polynoidea			1	1	2			1	2	3
		Number of classifications						14	11	11	15	28
		Sum of maximum counts						46	43	33	47	169

Table 8. Temporal and spatial distribution of acoustic transmitter detection across 15 species by receivers deployed at five ODMDS monitoring sites. For each species, row one denotes data between 22 January 2018 and 17 January 2019, and row two denotes data between 18 January 2019 and the end of monitoring at each site. For the number of transmitters, "Total*" denotes the number of unique transmitters per species per year.

		Number of transmitters						**Number of detections**					
Common name	*Scientific name*	HB2	HB3	HB4	I6	I5	*Total**	HB2	HB3	HB4	I6	I5	*Total*
Atlantic bluefin tuna	*Thunnus thynnus*					1	*1*					19	*19*
Atlantic bluefin tuna	*Thunnus thynnus*												
Atlantic sharpnose shark	*Rhizoprionodon terranovae*												
Atlantic sharpnose shark	*Rhizoprionodon terranovae*		1	2	1	2	*2*		31	11	3	4	*49*
Atlantic sturgeon	*Acipenser oxyrhynchus*	7	26	24	26	15	*62*	284	856	260	228	172	*1,800*
Atlantic sturgeon	*Acipenser oxyrhynchus*		30	28	31	21	*60*		358	203	691	112	*1,364*
Atlantic tarpon	*Megalops atlanticus*				1		*1*				2		*2*
Atlantic tarpon	*Megalops atlanticus*												
Blacknose shark	*Carcharhinus acronotus*		2	2			*2*		4	9			*13*
Blacknose shark	*Carcharhinus acronotus*			1			*1*			2			*2*
Blacktip shark	*Carcharhinus limbatus*	2	6	10	6	1	*17*	10	89	105	23	3	*230*
Blacktip shark	*Carcharhinus limbatus*		6	5	1		*7*		92	49	5		*146*
Bull shark	*Carcharhinus leucas*		1	1	2		*3*		3	7	13		*23*
Bull shark	*Carcharhinus leucas*		1	1	1	5	*6*		3	5	4	16	*28*
Cobia	*Rachycentron candadum*		2	4	7	5	*12*		144	38	174	65	*421*
Cobia	*Rachycentron candadum*		5	8	11	17	*23*		55	196	584	556	*1,391*
Common thresher shark	*Alopias vulpinus*												
Common thresher shark	*Alopias vulpinus*				1		*1*				15		*15*
Cownose ray	*Rhinoptera bonasus*		1	2	3	2	*7*		4	2	20	28	*54*
Cownose ray	*Rhinoptera bonasus*			3	5	4	*10*			12	33	52	*97*
Great hammerhead shark	*Sphyrna mokarran*	1	1	1		1	*2*	1	1	1		6	*9*
Great hammerhead shark	*Sphyrna mokarran*				1		*1*				1		*1*
Lemon shark	*Negaprion brevirostris*	1		2	1		*2*	1		7	2		*10*
Lemon shark	*Negaprion brevirostris*			1			*1*			3			*3*
Sandbar shark	*Carcharhinus plumbeus*		3	4	3	4	*6*		29	72	15	35	*151*
Sandbar shark	*Carcharhinus plumbeus*		1	1	1		*1*		3	4	1		*8*
Tiger shark	*Galeocerdo cuvier*		2	4	8	9	*10*		5	20	69	56	*150*
Tiger shark	*Galeocerdo cuvier*		5	7	10	16	*11*		21	60	82	146	*309*
White shark	*Carcharodon carcharias*	1		2	7	4	*10*	1		11	37	19	*68*
White shark	*Carcharodon carcharias*		13	14	2	14	*27*		115	178	16	85	*394*
To-be identified						1						1	*1*
To-be identified			1			1	*2*		1			4	*5*
# of codes, Year 1		*12*	*44*	*56*	*64*	*43*	*135*						
# of codes, Year 2		*0*	*63*	*71*	*65*	*80*	*153*						
# of detections, Year 1								*297*	*1,135*	*532*	*583*	*404*	*2,951*
# of detections, Year 2								*0*	*679*	*723*	*1,435*	*975*	*3,812*

Table 9. Temporal patterns in qualitative sediment type (top) and sand wave height (bottom) noted during diver video review across seasonal survey periods. Temporal monitoring sites are grouped as five sites surveyed in all seasonal periods, three sites surveyed in all but fall 2018, and four sites only surveyed in fall 2017 and spring 2018.

Seasonal survey	Sediment type	I2	I3	I4	I5	I6	I1	I8	HB3	I7	HB1	HB2	HB4
Fall 2017	Shell hash						x						
Fall 2017	Coarse sand		x		x		x		x				x
Fall 2017	Fine sand	x		x		x		x			x	x	
Fall 2017	Silt									x			
Spring 2018	Shell hash			x			x		x				x
Spring 2018	Coarse sand								x			x	x
Spring 2018	Fine sand	x	x	x	x	x	x				x		
Spring 2018	Silt							x		x			
Fall 2018	Shell hash												
Fall 2018	Coarse sand												
Fall 2018	Fine sand	x	x		x	x							
Fall 2018	Silt			x									
Fall 2019	Shell hash												
Fall 2019	Coarse sand				x				x				
Fall 2019	Fine sand	x	x	x		x	x	x					
Fall 2019	Silt												

Cycle	Sand wave height	I2	I3	I4	I5	I6	I1	I8	HB3	I7	HB1	HB2	HB4
Fall 2017	Large						x		x				x
Fall 2017	Small	x	x	x	x	x	x			x	x	x	
Spring 2018	Large						x		x			x	x
Spring 2018	Small	x	x	x	x	x	x	x		x			
Fall 2018	Large												
Fall 2018	Small	x	x		x	x							
Fall 2019	Large												
Fall 2019	Small	x	x	x	x	x	x	x	x				

Table 10. Mean (minimum – maximum) for the quantitative sediment composition, silt to clay ratio, and accumulation (weight per area per day) for the seafloor sediment and sediment traps for each survey period.

Gear Type	Time Period	Sand and CaCO3 (%)	Silt and Clay (%)	Sand (%)	CaCO3 (%)	Silt (%)	Clay (%)	TOM (%)	Silt/Clay Ratio	Sand phi	Weight ($g/cm^2/day$)
Sediment trap	fa17-sp18	62.15 (40.16-82.85)	37.85 (17.15-59.84)	49.92 (31.67-68.74)	12.23 (7.14-22.39)	15.13 (6.52-23.84)	22.72 (10.63-36.00)	11.89 (6.33-18.23)	0.67 (0.51-1.09)	2.83 (2.34-3.28)	0.147 (0.026-0.328)
	sp18-wi19	57.32 (38.55-74.35)	42.68 (25.65-61.45)	41.33 (21.61-61.65)	15.99 (12.70-18.41)	26.31 (13.72-44.63)	16.37 (10.30-27.13)	10.62 (6.50-17.88)	1.63 (1.14-2.78)	2.81 (2.59-3.30)	0.088 (0.042-0.134)
	wi19-fa19	76.89 (60.01-90.49)	23.11 (9.51-39.99)	60.00 (41.95-74.70)	16.88 (9.96-21.60)	10.59 (3.48-17.85)	12.52 (6.03-22.71)	11.20 (7.83-17.11)	0.86 (0.58-1.06)	2.70 (2.49-3.16)	0.122 (0.058-0.187)
Seafloor sediment	winter 2019	97.98 (96.27-98.92)	2.02 (1.08-3.73)	77.30 (50.24-90.70)	20.68 (8.22-47.22)	0.60 (0.09-1.07)	1.41 (0.70-2.65)	3.35 (0.92-4.84)	0.44 (0.10-0.95)	1.76 (-0.01-3.05)	
	fall 2019	97.77 (95.98-98.88)	2.23 (1.12-4.02)	82.93 (68.76-93.16)	14.84 (5.50-29.05)	0.24 (0.00-1.02)	2.00 (1.03-3.52)	3.48 (0.69-7.56)	0.11 (0.00-0.34)	1.87 (0.38-3.06)	

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Appendices

Appendix 1. Geographic location (latitude, longitude), depth range (feet), diver video survey dates, water temperature (°F), and visibility (feet) for 42 dive sites surveyed for this study.

				Depth (feet)		Fall 2017			Spring 2018			Fall 2018			Fall 2019		
Site	Latitude	Longitude	Total dives	Min	Max	Date	Viz	Temp	Date	Viz	Temp	Date	Viz	Temp	Date	Viz	Temp
I1	32.66540	-79.73860	6	40	44	5-Dec	20	66	2-May	8	65				6-Dec	10	57
I2	32.65180	-79.70930	6	45	50	5-Dec	20	64	2-May	15	68	15-Jan	5	57	6-Dec	10	58
I3	32.63290	-79.70200	5	45	51	5-Dec	35	66	30-Apr	20	68	15-Jan	8	55	6-Dec	10	58
I4	32.60960	-79.71730	18	54	62	5-Dec	35	66	30-Apr	15	65	17-Jan	7	55	29-Oct	30	75
I5	32.60480	-79.74020	9	44	51	22-Jan	45	57	30-Apr	12	65	15-Jan	7	54	6-Dec	28	58
I6	32.61850	-79.76950	8	44	51	22-Jan	40	55	1-May	8	64	17-Jan	4	54	16-Dec	5	59
I7	32.63740	-79.77680	4	50	54	22-Jan	5	51	2-May	5	66	17-Jan	4	55			
I8	32.66060	-79.76150	5	40	44	5-Dec	10	66	2-May	8	68	17-Jan	10	55	6-Dec	10	57
HB1	32.63180	-79.78600	2	49	50	22-Jan	10	54	2-May	12	68						
HB2	32.63040	-79.79200	7	48	52	22-Jan	10	51	1-May	5	68						
HB3	32.62920	-79.79800	5	46	50	22-Jan	10	53	2-May	10	68	17-Jan	5	55	16-Dec	3	59
HB4	32.63470	-79.79330	4	43	51	22-Jan	5	54	2-May	5	68	17-Jan	5	55			
E1	32.64250	-79.70500	1	43	43	29-Nov	20	63									
E2	32.64090	-79.70600	1	43	43	29-Nov	20	63									
E3	32.63100	-79.71260	1	44	44	29-Nov	20	63									
E4	32.62580	-79.71600	1	42	42	29-Nov	20	63									
E5	32.62480	-79.71660	1	44	44	29-Nov	20	63									
E6	32.62280	-79.71790	3	47	48	29-Nov	20	63									
E7	32.61820	-79.72090	1	53	53	29-Nov	20	63									
E8	32.61640	-79.72220	1	49	49	29-Nov	20	63									
E9	32.61440	-79.72350	1	54	54	29-Nov	20	63									
E10	32.61110	-79.72570	1	52	52	29-Nov	20	63									
S1	32.60720	-79.72930	1	49	49	30-Nov	30	64									
S2	32.60770	-79.73030	1	50	50	30-Nov	20	63									
S3	32.60950	-79.73420	1	50	50	30-Nov	20	64									
S4	32.61070	-79.73660	1	53	53	30-Nov	25	61									
S5	32.61350	-79.74270	1	47	47	30-Nov	20	61									
S6	32.61700	-79.75020	1	45	45	30-Nov	15	63									
S7	32.61910	-79.75460	1	48	48	30-Nov	15	61									
S8	32.62060	-79.75790	2	49	50	30-Nov	17	63									
S9	32.62310	-79.76310	1	47	47	1-Dec	15	62									
S10	32.62570	-79.76870	1	41	41	1-Dec	15	59									
W1	32.62810	-79.77370	1	46	46	30-Nov	10	63									
W2	32.62850	-79.77340	1	44	44	30-Nov	10	59									
W3	32.63720	-79.76770	1	32	32	1-Dec	15	59									
W4	32.64310	-79.76380	1	32	32	1-Dec	15	59									
W5	32.64660	-79.76150	1	34	34	1-Dec	10	59									
W6	32.64740	-79.76100	1	34	34	1-Dec	10	59									
W7	32.65040	-79.75910	2	35	40	5-Dec	10	64									
W8	32.65280	-79.75740	2	34	40	5-Dec	10	66									
W9	32.65450	-79.75630	3	41	41	5-Dec	15	64									
W10	32.65740	-79.75440	1	45	45	5-Dec	15	66									

Appendix 2. Geographic location (latitude, longitude), dates, depth (m), and deployment length for each sediment trap deployment.

Station Code	Station	Time Period	Date Deployed	Date Retrieved	Length of Deployment
OD_I1	I1	fa17-sp18	12/5/2017	5/2/2018	148
OD_I2	I2	fa17-sp18	12/5/2017	5/2/2018	148
OD_I3	I3	fa17-sp18	12/5/2017	4/30/2018	146
OD_I4	I4	fa17-sp18	12/5/2017	4/30/2018	146
OD_I5	I5	fa17-sp18	1/22/2018	4/30/2018	98
OD_I6	I6	fa17-sp18	1/22/2018	5/1/2018	99
OD_I7	I7	fa17-sp18	1/22/2018	5/2/2018	100
OD_I8	I8	fa17-sp18	1/22/2018	5/2/2018	100
OD_HB2	HB2	fa17-sp18	1/22/2018	5/1/2018	99
OD_HB3	HB3	fa17-sp18	1/22/2018	5/2/2018	100
OD_HB4	HB4	fa17-sp18	1/22/2018	5/2/2018	100
OD_I1	I1	sp18-wi19	5/2/2018	5/15/2019	378
OD_I2	I2	sp18-wi19	5/2/2018	1/15/2019	258
OD_I3	I3	sp18-wi19	4/30/2018	1/15/2019	260
OD_I4	I4	sp18-wi19	4/30/2018	1/17/2019	262
OD_I5	I5	sp18-wi19	4/30/2018	1/15/2019	260
OD_I6	I6	sp18-wi19	5/1/2018	1/17/2019	261
OD_I7	I7	sp18-wi19	5/2/2018	1/17/2019	260
OD_I8	I8	sp18-wi19	5/2/2018	1/17/2019	260
OD_HB2	HB2	sp18-wi19	5/1/2018	1/17/2019	261
OD_HB3	HB3	sp18-wi19	5/2/2018	1/17/2019	260
OD_HB4	HB4	sp18-wi19	5/2/2018	1/17/2019	260
OD_I1	I1	wi19-fa19	5/15/2019	10/2/2019	140
OD_I2	I2	wi19-fa19	1/15/2019	10/2/2019	260
OD_I3	I3	wi19-fa19	1/15/2019	10/2/2019	260
OD_I4	I4	wi19-fa19	1/17/2019	9/25/2019	251
OD_I5	I5	wi19-fa19	1/15/2019	12/6/2019	325
OD_I6	I6	wi19-fa19	1/17/2019	10/2/2019	258
OD_I7	I7	wi19-fa19	1/17/2019	12/16/2019	333
OD_I8	I8	wi19-fa19	1/17/2019	10/2/2019	258
OD_HB2	HB2	wi19-fa19	1/17/2019	12/16/2019	333
OD_HB3	HB3	wi19-fa19	1/17/2019	12/16/2019	333
OD_HB4	HB4	wi19-fa19	1/17/2019	12/16/2019	333

Appendix 3. Acoustic transmitters detected in the ODMDS study area between 22 January 2018 and a maximum of 16 December 2019 were deployed across 15 species by 36 research groups, with eight species tagged by multiple groups.

Affiliation	Researcher	*Atlantic bluefin tuna*	*Atlantic sharpnose shark*	*Atlantic sturgeon*	*Atlantic tarpon*	*Blacknose shark*	*Blacktip shark*	*Bull shark*	*Cobia*	*Common thresher*	*Cownose ray*	*Great hammerhead shark*	*Lemon shark*	*Sandbar shark*	*Tiger shark*	*White shark*
A&F	Debbie Abercrombie							x								
BBMS	Matt Smukall; Maurits VZB; Vital Heim							x				x				
BTT	Aaron Adams; Andy J. Danylchuk; Lucas Griffin				x											
CCU	Caroline Collatos													x		
CCU	Jeremy Arnt							x					x			
DEDNREC	Ian Park			x												
DSU	Dewayne Fox			x												
FAU	Beth Bowers; Stephen Kajiura						x									
FAU	Matt Ajemian							x								
FWC	Joy Young								x							
GADNR	Chris Kalinowsky								x							
KSC	Eric Reyier		x			x										
MADMF	Greg Skomal; John Chisholm; Megan Winton															x
MDDNR	Charles P. Stence			x												
NCDMF	Anne Markwith; Steve Poland								x							
NCSU	Jeffrey A. Buckel; Riley Gallagher								x							
OCEARCH	Christina LoBuglio; Bryan Franks															x
OCEARCH	Christina LoBuglio; Bryan Franks; Bryan Frazier														x	x
OCEARCH	Christina LoBuglio; Bryan Franks; Tobey Curtis															x
SCDNR	Bill Post et al.			x												
SCDNR	Bryan Frazier						x								x	
SCDNR	Justin Yost; Matt Perkinson								x							
SERC	Charles Bangley										x					
SERC	Matt Ogburn; Tuck Hines						x	x								
SERC/VIMS	Matt Ogburn; Bob Fisher										x					
Shedd	Steven Kessel												x			
SU	Barbara Block; Michael Castelton	x														
SUNY	Evan Ingram			x												
SUNY	Keith Dunton			x												
SUNY	Ollie Shipley									x						
UGA	Doug Peterson			x												
UM	Neil Hammerschlag; Austin Gallagher							x							x	
USN	Carter Watterson; Chris Hager			x												
VCU	Matt Balazik			x												
VIMS	Eric Hilton			x												
VIMS	Kevin Weng, Dan Crear								x							
	Number of research groups	*1*	*1*	*10*	*1*	*1*	*3*	*6*	*6*	*1*	*2*	*1*	*2*	*1*	*3*	*4*